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A QUANTITATIVE ANALYSIS OF METHODS USED FOR AVOIDANCE AND
ACCELERATION OF DEVELOPMENTAL MATHEMATICS SEQUENCES IN
COMMUNITY COLLEGE

Steven T. Travers

148 Pages

Many developmental mathematics programs at community colleges in recent years have undergone a process of redesign in an attempt increase the historical poor rate of student successful completion of required developmental coursework. Various curriculum and instructional design models that incorporate methods of avoiding and accelerating the developmental mathematics requirements have been created in an effort to increase the retention and course completion rate of students placed in developmental mathematics programs. It is believed that developmental students need developmental mathematics courses in order to build a strong mathematical foundation; this will enable them to achieve their desired higher education goals. The purpose of this research was to investigate a developmental mathematics program redesign model that uses a modularized, self-paced, computer-based mathematics instruction model developed to provide mastery learning of mathematics, while at the same time reducing the number of semesters required for students to progress through their developmental mathematics courses.

Using a theoretical framework based on concepts in Tinto's (1993) *Longitudinal Model of Individual Departure from Institutions of Higher Education*, this study specifically investigated how dual enrollment courses taken in high school, rural residency of students, and

the use of computer-based developmental mathematics instruction impacted course grades, course completion, and degree attainment of developmental mathematics students at Heartland Community College in Normal, Illinois. A quantitative analysis using a combination of Pearson's Chi-square analysis, independent samples *t*-tests, and binary logistic regression was completed to investigate the relationship between the independent variables of dual enrollment, rural residency, and computer-based developmental mathematics instruction and the dependent variables of course grades, course completion, and degree attainment. In addition, the independent variables of age, gender, ethnicity, year in school, and ACT mathematics exam scores were analyzed as control variables.

Results of the study indicated that developmental mathematics students at Heartland Community College who had completed dual enrollment courses in high school, completed courses and obtained degrees at higher rates than non-dual enrollment students. Black students were the most negatively impacted by developmental mathematics courses than other ethnicities. Rural students completed courses and obtained degrees at higher rates than non-rural students. These results indicated that the technological infrastructure in rural areas had no impact on student achievement. Analysis indicated that the influence of the lesser course completion and degree attainment rates of non-rural developmental mathematics students may have been due to the large, non-rural population of black students who completed courses and attained degrees at lower rates than other ethnic groups. In computer-based mathematics courses, students taking the course online had reduced course completion and degree attainment rates versus those students who took computer-based developmental mathematics on-campus. Lastly, the

redesigned developmental mathematics program appears to have reduced the number of students completing courses and attaining degrees in comparison to the previous traditional developmental mathematics program.

KEYWORDS: Quantitative analysis; Developmental mathematics; Community college; Computer-based mathematics; Dual enrollment; Rural residency; Course completion; Degree attainment

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STEVEN T. TRAVERS

A Dissertation Submitted in Partial
Fulfillment of the Requirements
for the Degree of

DOCTOR OF EDUCATION

School of Teaching and Learning

ILLINOIS STATE UNIVERSITY

2017

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ACCELERATION OF DEVELOPMENTAL MATHEMATICS SEQUENCES IN
COMMUNITY COLLEGE

STEVEN T. TRAVERS

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ACKNOWLEDGMENTS

I would first like to thank my committee, Dr. Alan Bates, Dr. Steven Mertens, and Dr. Chris Merrill for their patience, support, and guidance throughout this dissertation process. Their encouragement and thoughtful feedback provided me with the extrinsic motivation that I often needed when my intrinsic motivation was fading. Without their dedication to my work, this process would have been nearly impossible.

I would also like to thank my immediate and extended family for all of their support. My parents, Thomas and Marilyn Travers for always supporting my educational pursuits, no matter how varied they were over the years; their continuous support never went unnoticed or unappreciated. My siblings, Mark, Charlotte, and Chris for providing me three good role models to always look up to and strive to be as good as. I would be amiss to not say thank you to my in-laws, Wayne and Cathie Lockwood, for giving their time, encouragement, and support throughout these last few years. Lastly, I would like to thank my wife Kimberly and son Conner for providing me with more than they will probably ever know. I could not have completed this process without them.

S.T.T.

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CHAPTER I: INTRODUCTION

Overview

For years, the effectiveness and necessity of developmental programs have been an intensely debated topic in higher education because the courses have been shown in research to act as a pathway and a barrier to academic success (Bonham & Boylan, 2012). Developmental courses offer students lacking college level academic skills a pathway to pursuing their higher education academic goals by providing them needed minimal skills needed to succeed in college level courses. However, relatively few students are successful in completing the necessary developmental courses that allow them to move on to higher level, or college level courses in school (Bahr, 2008). For instance, a study by Bahr (2008) of community college students in California indicated 81.5% of students placed into developmental mathematics courses in two-year colleges never earned a degree or certificate, or transferred on to a four-year university (p. 444).

In addition to the lack of apparent success in developmental programs, many opponents believe offering developmental courses in higher education diminishes high school student motivation to enroll in higher level mathematics courses while in high school (Bahr, 2008; Oudenhoven, 2002). Some believe developmental courses “dumb down” college courses and inflate academic costs by repeating courses that are already offered in PK-12 (Bahr, 2008; Oudenhoven, 2002). Many of these developmental course opponents believe developmental programs can diminish the status of higher education institutions, and devalue the higher education instructor by requiring them to teach courses considered below college level (Bahr, 2008; Oudenhoven, 2002). Regardless, many educators and researchers believe developmental programs in higher education are an important piece in solving not only educational problems,

but also a significant factor for helping alleviate social and economic issues (Oudenhoven, 2002).

In recent years, government policy makers have placed pressure on higher education institutions to improve the completion rates of these programs (Bailey, Jeong, & Choo, 2010). Higher education funding is one of the major influences that policy makers have used to place pressure on academic administrators to create developmental programs that will hopefully improve college completion rates. The amount of funding available to higher education institutions is often negatively affected by a lack of improvement being shown in student completion rates within developmental programs (Cafarella, 2016a). Redesign of traditional developmental programs has become necessary in many higher education institutions due to funding requirements in many schools and the apparent lack of success for students in these programs (Cafarella, 2016a).

Developmental Mathematics

Developmental mathematics courses are pre-college level courses that teach primary and secondary academic level skills to students deficient in requisite college level mathematic skills for enrolling in college level algebra or other college level mathematics courses (Community College Research Center, 2014). Developmental mathematics programs typically incorporate a group of course that include arithmetic, elementary algebra, and intermediate algebra (Ariovich & Walker, 2014). Depending on the mathematic deficiencies of the student, one semester or up to four semesters of courses may be required before a student is considered ready for college level mathematics (Ariovich & Walker, 2014). Typically, students are placed into specific semesters of coursework depending on placement exam scores and/or other mathematics assessments such as SAT or ACT college entrance exam scores. Additionally, developmental

mathematics courses, and other developmental courses required to be taken by students, are typically non-credit courses because the courses are pre-college level.

Recent Approaches to Developmental Mathematics

Even with the relative few numbers of students successfully completing developmental programs, research has shown students who complete their developmental sequence tend to be successful in later coursework (Bonham & Boylan, 2012). Considering that nearly one-third of all first year students enrolled in public two-year and four-year institutions are underprepared academically for one or more college-level courses, methods that improve the support of students passing developmental courses and moving on to college level courses appears to be a worthwhile endeavor (Moss, Kelcey, & Showers, 2014). Bahr (2008) indicated community college students who complete a developmental mathematics program achieve academically at an essentially equivalent level as community college students not required to take developmental mathematics courses.

Several methods of redesign for developmental mathematics have been used in an attempt to increase retention and completion of developmental programs. Among methods to assimilate underprepared students into higher education are methods for avoidance, such as dual enrollment courses in taken in high school, and acceleration methods such as reducing the length of the course to less than 16 weeks and contextualizing the curriculum (Rutschow & Schneider, 2011).

Computer technology has also become an integral component in many developmental mathematics programs. With the increased use of technology in the classroom and in everyday life by students, computers have been leveraged in an attempt to transform learning (Spradlin & Ackerman, 2012; Zientek, Skidmore, Saxon, & Edmonson, 2015). Computer-aided instruction

in developmental mathematics ranges from computer-based course supplements, computer-based instruction, blended/hybrid courses, and online courses (Spradlin & Ackerman, 2012).

Developmental course design changes may have been “forced” in higher education by funding policies, but in reality, traditional methods of remediation that have been in practice for years appeared to be in dire need of change. As stated by Boylan (1999), “If traditional teaching methods had worked for those students, they would not be taking remedial courses” (p. 3).

Developmental Mathematics in Community Colleges

Developmental mathematics is one developmental program that has been targeted and scrutinized by educators and policy makers as a key to providing career and higher education pathways for students. Although deficits in learning can be found in any subject area, mathematics is a subject that affects a large population of students (Bonham & Boylan, 2012). The National Center for Education Statistics (NCES) conducted a longitudinal study that found 42% of students beginning in higher education were underprepared for mathematics and required to enroll in a developmental mathematics course (National Center for Education Statistics, 2012). The high number of beginning post-secondary students needing developmental mathematics courses is complicated even more by low retention rates. In a study of community colleges across California, Bahr (2008) found student non-completion rates of 81.5% in developmental mathematics programs (p.444). High attrition from developmental mathematics programs has increased pressure on college administrators to find instructional methods that increase retention of developmental mathematics students through developmental course sequences and obtain higher rates of degree/certification completion or transfer to four-year universities (Cafarella, 2016a).

Although both two- and four-year post-secondary institutions offer developmental programs, community colleges are an important resource for remediating student mathematic deficits. Students attend community colleges for a variety of reasons, but many who enroll are underprepared for college level coursework. The majority of community college students are non-traditional higher education students that, as stated by Bailey (2009), “arrive unprepared to engage effectively in the core function of college” (p. 1). When considering the open door admission policy of community colleges, beginning students underprepared for college level coursework is not surprising. Because of the student demographic profile of community college students, these institutions have been identified as key targets for developing innovative developmental mathematics programs that can play a key role in developing a competitive workforce and serving as gateways to four-year education institutions (Bonham & Boylan, 2012; Rutschow & Schneider, 2011). As stated by Ariovich and Walker (2014) “as the federal and state governments pay more attention to student success and degree completion, reforming developmental mathematics has become a priority for community college leaders” (p. 45).

The majority of community colleges are open access higher education institutions that are used by nearly half of undergraduate students in the United States (American Association of Community Colleges, 2016a). As stated by Rutschow & Schneider (2011):

One of the greatest challenges that community colleges face in their efforts to increase graduation rates is improving the success of students in their developmental, or remedial, education programs—the courses that students without adequate academic preparation must take before they can enroll in courses for college credit. (p. iii)

As Hodura (2011) states, “the academic outlook for students who enroll in developmental mathematics courses is generally unfavorable” (p. 29). As noted by Cafarella (2016b), student

success and attrition in developmental courses in college are poor. Poor course completion rates for developmental mathematics students negatively impact their ability to continue on to college level mathematics courses and be successful in college (Hodura, 2011). Increased student success has been observed when students complete two or more developmental mathematics courses (Bettinger & Long, 2006). The importance of community colleges providing a developmental mathematics program that provide a strong mathematics foundation that is capable of promoting student persistence, is an essential part of supporting future professional and academic success for underprepared college students.

Statement of Problem

Developmental mathematics, as with other developmental courses in higher education, is used to develop student subject content knowledge to a level that enables them to perform at a skill level that is considered to be college level. Although most two-year colleges and four-year universities offer some type of mathematics remediation (Brothen & Wambach, 2012), two-year colleges most often have an open-enrollment policy that allows for students with limited mathematics knowledge, and other basic educational skills, to pursue higher education. The obvious effect of open-enrollment policies at two-year schools is the large population of underprepared students at these institutions. For this reason, developmental programs are vital for supporting these students with skills that prepare them for successful entrance to either the workforce or four-year universities. Developmental programs are essential to promoting the American ideal of everyone having an equal opportunity to higher education (Brothen & Wambach, 2012). With the questions concerning the necessity and/or benefits of developmental mathematics programs, and the recent changes to those programs that are hoped to improve

developmental program completion, research on the outcomes from these programs can be used to guide further refinements of developmental programs.

One of the recent trends in higher education has been the elimination of developmental mathematics programs from four-year universities (Brothen & Wambach, 2012). The elimination of these programs has helped lead to developmental programs now being offered in all community colleges in the United States (Brothen & Wambach, 2012). However, due to underprepared students still being part of the student population at many four-year universities, and the open door admittance policy at most two-year colleges allowing for the entrance of academically underprepared students, developmental programs are still a necessity in higher education (Brothen & Wambach, 2012).

In recent years, the benefits of developmental programs in higher education have been questioned. Even though developmental mathematics programs are designed to create the necessary academic skills to support student academic and professional pursuits, retention through developmental sequences by students is relatively low in terms of the total number of students recommended to these programs (Bailey, Jeong, & Choo, 2010). Developmental mathematics programs are intended to support students academically, but research on the success of developmental programs is mixed (Bettinger & Long, 2006). Research has shown developmental mathematics can promote student retention (Bettinger & Long, 2006) and benefit student academic pursuits (Brothen & Wambach, 2012), but other research has indicated required developmental course sequences can be a hindrance to educational success (Boatman and Long, 2010). With the most underprepared mathematics students beginning their college career needing up to four semesters of costly, non-credit mathematics courses, developmental programs can create a financial and time barrier to developmental student academic goals. A

costly, non-credit, multi-semester sequence of developmental courses creates a program that provides academically and financially disadvantaged students numerous opportunities to exit the developmental sequence (Hern, 2012; Jaggars, Hodara, Cho, & Xu, 2015). Without the completion of a required developmental mathematics sequence, achieving most academic goals, such as a degree or certificate, becomes extremely difficult.

Developmental mathematics programs in higher education have seen many changes to the curriculum and instruction in recent years. The redesigned programs were developed to improve student retention and completion of programs while at the same time improving mathematics concept mastery. Although research has been completed by many scholars on these newer developmental mathematics programs, much of the research is limited (Rutschow & Schneider, 2011). In many of the newly designed developmental mathematics programs, multiple methods of supporting students are implemented, and much of the research that shows positive outcomes for these programs (Booth, Capraro, Capraro, Chaudhuri, Dyer, & Marchbanks, 2014), have not evaluated specific student supports. Research is needed in higher education developmental mathematics programs to determine if one or several of the newer developmental methods can be individually correlated to positive outcomes for students (Jaggars, Hodara, Cho, & Xu, 2015; Rutschow & Schneider, 2011). Research may show support for students in developmental mathematics programs using a variety of support methods but a closer look at individual parts of the program may indicate individual parts that are providing the most support. An analysis of individual developmental mathematics student supports is needed to determine if individual, or a combination of avoidance, acceleration, and contextualization support methods are providing a benefit to students. In addition, does the increased dependence

on computer instruction in the classroom or in distance learning help or hinder the developmental mathematics student in community college.

Purpose of the Study

The primary purpose of this research was to investigate the impact of dual enrollment courses, rural residency, and computer-based instruction in community colleges on course grades, retention in courses, and attainment of degrees. The academic success of rural online learners was compared to non-rural learners to find if there is a significance in student learning outcomes based on student home location. Traditional developmental mathematics courses were also compared to computer-based developmental mathematics courses to see if there is a significant difference in student retention and academic achievement using those different course designs.

The variables of dual enrollment, location of student's home, and the instructional methods (traditional classroom, computer-based, and online) were investigated to find if a relationship between these variables and student grades, course completion, and degree attainment for students in developmental mathematics existed.

Significance of the Study

Approximately 60% of community college students start their first semester of their college career in developmental courses, and less than half of these students complete or pass the course (Rutschow & Schneider, 2011). In addition, only about 28% of students who take a remedial course end up earning a degree within eight years (Community College Research Center, 2014). Many institutions have begun to reform developmental mathematics programs in recent years using various methods believed to improve student retention, developmental mathematics sequence completion, and degree/certificate obtainment. Much of the research on

the effectiveness of these reforms have been in programs with relatively newly redesigned developmental programs, and any gains in student successes have been only modest. Many of the promising redesigned developmental programs have only improved students' academic achievement by a few percentage points but a "small change relative to the large number of students failing developmental education courses" (Rutschow & Schneider, 2011, p. 53).

This study presents information obtained from the analysis of twenty-three semesters of community college developmental mathematics student data. The information obtained from the analysis of student data from this twenty-three semester period provides information that is useful in helping community colleges decide how to best support the developmental mathematics student. Considering the number of students affected by placement in developmental mathematics, and the negative effects that are attributed to being a developmental student, any additional research that can help better the designs of developmental mathematics programs may be beneficial to the field.

In addition, this research was attempting to narrow the evaluation of a developmental mathematics programs into specific factors related to designs that help students avoid the need for extensive developmental mathematics sequences. Additionally, the effect that these programs apparently have in helping student success required to take developmental mathematics courses was also investigated. As mentioned previously, successful completion of college is negatively impacted by developmental coursework (Rutschow & Schneider, 2011). Dual enrollment programs investigated in this study are programs that help students mentally prepared for college, and eliminate or reduce the need for developmental mathematics programs by offering college courses to high school students. Dual enrollment programs may also support the retention of students in college by eliminating the need for developmental courses or by

reducing the number of courses needed. Reducing the length of time in these developmental programs, or the need for these programs at all, has shown evidence of improving the retention of students in higher education (Hern, 2012).

Rural students were investigated in this study because rural students often have academic and location characteristics that are considered detrimental to them when pursuing studies in higher education (Leist & Travis, 2010). As Leist and Travis (2010) state, “no other sector of higher education is more affected by geography than rural community colleges” (p. 18). Although the community college in this study, Heartland Community College, is not a rural community college, the college does serve many rural students. Research by Aragon and Johnson (2008), Cejda (2013), and Leist and Travis (2010), indicated smaller, rural community colleges tend to have larger populations by percentage of total students of underprepared, lower socio-economic class, older, first-in-family, and time obligated students.

The developmental mathematics program investigated in this research is a redesigned program that went from a traditional face-to-face classroom developmental mathematics program to a lab situated, computer-based instruction format that incorporates the use of online learning modules for delivery of the curriculum and instruction. Learning modules that are accessed through the computer system on-campus are accessed through the Internet for working off-campus. As stated by Cejda (2010) “broadband connection in rural homes lags 19% behind that of urban homes and 22% behind that of suburban homes” (p. 13). With the many obstacles associated with non-traditional students in two-year schools, rural students may face even more obstacles than students living in urban and suburban areas because of inferior technological infrastructure and reduced access to the Internet. Investigation of the rural variable in computer-based developmental mathematics was completed to determine if Internet access impacted the

success of rural students in comparison to non-rural students. It was believed that gaining an understanding of how computer-based developmental mathematics courses, either taken at the school or online by rural students, impact successful completion of developmental mathematics courses and degree attainment for students based on residency would be important information for helping improve the design of developmental mathematics programs.

This study also investigated the impact on students who take computer-based developmental mathematics on-campus and online. Research at two-year higher education institutions indicates online courses do not have significantly greater student failure rates in comparison to traditional classes, but online courses do have significantly lower completion rates (Xu & Jagers, 2011). Attrition from developmental courses is hoped to be reduced by acceleration through the programs using strategies such as computer-based modular programs. The rate at which a student moves through a computer-based modular course is determined by the motivation and content knowledge of the student; the course pace is not determined by the academic calendar, rate of instruction, or the knowledge level of other students like in a traditional lecture course. With this study looking at the academic success of developmental mathematics students in a modularized computer-based courses that are both on-campus and online, this study revealed information regarding the use of online courses in computer-based developmental mathematics courses. Computer-based developmental mathematics courses have many characteristics similar to hybrid or blended courses, so gaining an understanding of the impacts these types of courses on developmental mathematics student success was hoped to be found.

Theoretical Perspective

The theoretical perspective in this research is based on concepts in Tinto's 1975 theory, *A Longitudinal Model of Dropout* and 1987's refinement, *A Longitudinal Model of Individual Departure from Institutions of Higher Education* (Tinto, 1975, 1993). As stated by Tinto (1993)...

Individual departure from institutions can be viewed as arising out of a longitudinal process of interactions between an individual with given attributes, skills, financial resources, prior educational experiences, and dispositions (intentions and commitments) and other members of the academic and social systems of the institution. (p. 113)

According to Tinto (2006), the personal characteristics that relate to a student's culture, social status, and economic status are important influences on student attrition from higher education, but institutions can help negate these characteristics through processes within the institution. Especially important in retaining first-year students are faculty and classroom practices, with faculty interactions with students in traditional courses particularly improving student retention (Tinto, 2006). Faculty and peer interactions promote student involvement in the classroom and institution, which in turn strengthens the feeling of belonging and commitment to school (Tinto, 1993, 1997, 2006; Tinto, Russo, & Kadel, 1994).

Computer-based instruction reduces faculty/student and student/student interaction in the classroom. Developmental mathematics programs that use computer-based instruction, especially considering that developmental courses are often first semester, first-year courses, reduce important academic and social interaction within the classroom that supports student academic inclusion. The classroom interaction is especially important in commuter higher education institutions such as community colleges, where student activities are often not

considered a priority for students who commute and time is impacted by external commitments (Tinto, 1993; Tinto, 2006). Social interactions that promote student academic inclusion for commuter students at community colleges may only happen in the classroom and “if involvement does not occur there, it is unlikely to occur elsewhere” (Tinto, 2006, p.4). The computer system, used as a method for delivering course content, removes much of the support system provided by educational and casual discussions between the instructor and student. Integration both academically and socially to college can be difficult for community college students because they are often only on campus to take classes. Many community college students are also not available to participate in academic or social extracurricular activities due to other obligations such as work and family. “The classroom is often the only place where they meet other students and the faculty. If involvement does not occur in those smaller places of engagement, it is unlikely it will occur elsewhere” (Tinto, 1999, p. 4). The first year of the studies in higher education, which is the typical time of enrollment in a student's first developmental course, is an especially important time to provide engagement to promote integration and support student retention (Tinto, 2006). Using computer-based as the basis for course content delivery, whether it be in the classroom or at a distance, may play a negative role in the retention of community college students because computer-based instruction reduces the social and academic interactions that take place in the traditional classroom. Active classroom involvement between students teaching and learning from each other promotes greater effort, better learning, and greater success in students (Tinto, 1999). Involvement in classroom learning, especially with other students, leads to greater quality of effort, enhanced learning, and in turn heightened student success

The first year of higher education, according to Tinto (2006), is an especially critical time for students to gain a feeling of belonging in higher education. Processes that ease the transition from secondary school to post-secondary school should be important to promoting student inclusion and retention in the institution. Dual enrollment courses offered during secondary school provide students with an introduction to higher education that may ease the transition to higher education. Integration of students to post-secondary education should be supported by dual enrollment courses taken in high school.

According to Tinto (1999), for students to be successful there needs to be (a.) institutional commitment, (b.) high expectations for the students, (c.) academic, social and economic student supports, (d.) faculty, staff, and student monitoring and feedback, and (e.) student integration both academically and socially. Based on Tinto's (1999) ideas, the dual enrollment program at Heartland Community College in Normal, Illinois was studied to determine if dual enrollment appears to support student integration into higher education. Computer-based developmental mathematics instruction was also studied to determine if the lack of student/student and student/faculty interaction negatively effected student retention. Lastly, the residency of students was studied to determine if students indicating a rural home addresses were negatively impacted by diminished internet accessiblity that limited their access to computer-based learning in their developmental mathematics courses.

Research Questions

Three research questions were developed for this study based on dual enrollment, student home location, and the instructional method used in developmental mathematics courses at the study location.

RQ 1: Are students who have taken dual enrollment courses in high school more academically successful in a computer-based developmental mathematics courses and programs than students who have not had dual enrollment courses?

RQ 2: Are students who live in rural areas academically less successful in computer-based developmental mathematics than students who live in non-rural areas?

RQ 3: Does the curriculum and instruction delivery method used in developmental mathematics have a significant relationship with successful course completion and degree attainment in academic programs of study?

Research Method

As stated by Creswell (2012), “In educational research, your objective may be to relate variables rather than manipulate the independent variable, as in an experiment. If so, your design is correlational research” (p. 339). For purposes of this research, a predictive correlational quantitative study of a computer-based developmental mathematics program at a community college was completed. The impact of dual enrollment, rural residency designation, and course delivery method was investigated to determine if these variables have a significant impact on course scores, course completion rates, and degree attainment at community college.

The statistical analysis revealed evidence on the extent of, 1) dual enrollment promoting student integration as reflected in their success in completing developmental mathematics courses and obtaining degrees, 2) rural residency on course completion and degree attainment of students who took computer-based developmental mathematics courses, and 3) computer-based course delivery method on the course completion rates and degree attainment of students. The results of the analysis provides some information that can help guide the best path for students to proceed in order to successfully make it through developmental mathematics courses and attain

degrees, and what potential negative impacts can be minimized to help students in their academic pursuits.

Definition of Terms

Developmental mathematics. As stated by Kinney (2001), is a course or program designed to “develop in at-risk, underprepared college students the educational skills, knowledge foundation, and disposition for continued learning that will permit them to transfer to degree-granting colleges and pursue degree programs with a reasonable probability of success” (p.11). Developmental mathematics courses are most often mathematics courses in arithmetic and algebra (Ariovich & Walker, 2014).

Dual enrollment courses. College courses that high school students enroll in while still in high school. As stated by Chumble (2015), “dual enrollment programs are collaborative efforts between high schools and colleges where high school students (usually juniors and seniors) are permitted to enroll in actual college courses, often on a college campus, rather than a college-level course on the high school campus” (p. 29). Dual enrollment courses not only provide high school students to take college courses early but it provides as a method for preparing students for the transition from PK-12 to higher education. Generally high school students receive college credit for passing dual enrollment courses, but in the case of developmental courses, students generally do not receive college credit because the courses are not considered college-level courses. For purposes of this research, dual enrollment courses specifically refer to college courses offered on-campus to students while still in high school.

Rural. For the purposes of this research, rural is a geographical area outside of areas designated as urban areas (groups of 50,000 or more people) or urban clusters (2,500 to less than 50,000 people) is considered rural (United States Census Bureau, 2015). For purposes of this

research, any area outside of an urban built-up area, or an urban built-up area with a population of 2,499 or less and a population density of 500 individuals per square mile is considered rural (United States Department of Agriculture Economic Research Service, 2017).

Non-rural. Metropolitan areas that meet the United States Census Bureau’s designation of urban areas or urban clusters. Although not identical in all aspects, for purposes of this research, suburban and urban areas are those areas that are not rural and have a population cluster of 2,500 or more people (United States Census Bureau, 2015). For purposes of this research, non-rural is any area that does not meet the definition of rural.

Computer-based instruction. The use of computer software for instruction of the curriculum and assessment within a course. Computer-based instruction can be delivered via classroom or online. Typically, within a “brick and mortar” school, the traditional classroom is replaced by a computer lab. Computer-based learning is a student-centered method where students are able to work through the curriculum at their own pace, spending more time on difficult concepts and less time on concepts that are familiar. Teachers in computer-based classrooms take on a classroom role that resembles a tutor more than an instructor. Teachers in these classrooms keep track of student course progress and communicate the progress to students. In the classroom teachers answer individual questions when needed and assist with the assessment procedures.

Hybrid/blended course. A course where a portion of the traditional “seat time” in a classroom is substituted with online activities (Simonson, Smaldino, & Zvacek, 2015). In a hybrid/blended course, anywhere from 25% percent to 75% of the course content is presented using traditional face-to-face methods (Quality Matters, 2016).

Online course. A course where the instruction of the curriculum is facilitated by entirely by technology and only a few, if any, traditional face-to-face class meetings take place.

CHAPTER II: LITERATURE REVIEW

Brief History of Developmental Mathematics in Higher Education

Developmental programs in higher education are an important part for building a foundation for success of students. Although remediation of higher education students could be argued as beginning in the 1600's with Harvard University providing Latin and Greek tutors to underprepared students, structured remediation programs are often attributed as a necessary response to the G.I. Bill that provided vast numbers of academically unprepared military veteran access to higher education (Renfro & Amour-Garb, 1999). The Morrill Act of 1862 created numerous land grant universities across the United States that provided open access, higher education to state citizens who had completed their high school education (Renfro & Amour-Garb, 1999). Many institutions in the mid-20th century remained open access, and the financial means being available to large numbers of high school graduates that had served in the military during World War II (WWII) and the Korean Conflict, many universities were forced to limit enrollments (Renfro & Amour-Garb, 1999).

The two-year public, community college system was proposed by the Truman Commission in 1948 in response to the large numbers of students seeking higher education that now faced exclusion from four-year universities due to academic entrance requirements and increased tuition costs (American Association of Community Colleges, 2016b). Although two-year community colleges have been in existence since 1901, post WWII economic development, the G.I. Bill, and "Baby Boomers" reaching college age, the 1960's saw a large increase in the number of community colleges and the formation of a national network of community colleges (American Association of Community Colleges, 2016b). Community colleges became the higher education institution of choice for many financially underprivileged and academically

underprepared higher education students. The large populations of underprepared students that attend community college have made remediation courses a necessity of institutions.

The purpose of remedial courses is to remediate a deficiency in academic disciplines. The academic deficiency is when students are not considered to be at a college level within a discipline. Although academic remediation can be associated with several academic disciplines, the majority of remedial courses are offered in mathematics, reading, and English.

The term “remedial” is often used interchangeably with “developmental” when referring to academics, but changes in recent years in higher education have emphasized a move from the mere goal orientation of remedial instruction to developmental instruction that targets the improvement of student academic abilities and processes (Ross, 1970). Redesign of remediation to a more student-centered developmental education has created a shift in the teaching strategies that include modifications to the “content, organization, and delivery” of mathematics programs (Bonham & Boylan, 2012).

Recent Redesign Approaches in Developmental Mathematics Programs

Developmental mathematics programs, as stated previously, have generally been structured as a sequence of courses including both arithmetic and algebra intended to remediate missing mathematics ability through traditional coursework (Ariovich & Walker, 2014). With the mixed results of these remedial courses appearing to have varying success for students in completing a degree, staying in school, or moving on to college gateway mathematics courses, redesign of these mathematics courses has changed to more developmental in nature (Ariovich & Walker, 2014).

In recent years, mathematics programs have evolved from merely targeting remediation to developing cross-content academic skills that promote academic success. These programs

now serve not only as a method of remediating student mathematics skills to a level to which they can enroll in college level mathematics courses or other college level mathematics required courses, but they also develop students learning skills to prepare them for all courses in higher education (Mathematics Special Professional Interest Network, National Association for Developmental Education, 2002). A subtle third outcome of developmental programs is they provide support to students motivated to succeed in higher education but are lacking the skills to succeed at their goals (Mathematics Special Professional Interest Network, National Association for Developmental Education, 2002).

With the low rates of developmental mathematics success, students failing or withdrawing, only completing part of the developmental sequence, or never enrolling in developmental mathematics courses, higher education institutions have begun to modify their program structure and curriculum to attempt to improve student success (Ariovich & Walker, 2014). Popular methods of course redesign include various methods that accelerate the student time to completion either through modifications to instruction and/or curriculum (Edgecombe, 2011). In addition, academic courses taken in secondary school or prior to the first semester of college are also important to developmental mathematics redesign.

Avoidance Methods

Included in these modifications are avoidance programs such as dual enrollment courses and early assessments that students take in high school, and Summer Bridge program courses. These programs are designed to allow students to be assessed in high school for deficiencies in mathematics, and if they exhibit deficiencies then they can enroll in a bridge course, a short course often offered in the summer after graduating high school and before starting college that attempts to eliminate deficiencies prior to enrolling in higher education (Rutschow & Schneider,

2011). Allowing students to improve their mathematics skills before entering higher education and preparing them mentally for the coursework ahead may help students score better on placement exams, and therefore possibly avoid developmental mathematics courses altogether (Rutschow & Schneider, 2011). With developmental mathematics being an obstacle to many students in higher education, avoidance of the programs altogether should promote students in their higher education pursuits by easing the transition to higher education and promoting academic integration.

Dual enrollment. Dual enrollment courses allow students to take courses for college credit or zero-credit college courses that count as developmental work while still in high school (Kim, 2012; Rutschow & Schneider, 2011). Dual enrollment courses may be offered at either the secondary school that the student is enrolled, at a college campus, or at different locales affiliated with either school (Rutschow & Schneider, 2011). Dual enrollment courses are not specific to developmental programs, dual enrollment courses in any academic area may be important for students who are not prepared academically or mentally for higher education. As noted though by Kim and Bragg (2008) in their study of effectiveness of dual enrollment in four community colleges in Florida, Ohio, Oregon, and Texas, dual enrollment “literature abounds with positive and negative claims but is scarce with outcome studies” (p. 135). Dual enrollment though appears to be an important part of the redesign of developmental programs in community college because of the potential for these programs to aid students in avoiding higher education remediation and college attrition by preparing students for higher education (Kim & Bragg, 2008; Rutschow & Schneider, 2011).

Dual enrollment initiatives for developmental students have been adopted in seven states as of 2015 (Education Commission of the United States, 2015). “In 21 states and the District of

Columbia, there is no state policy on dual enrollment but through local agreements between high schools/school districts and higher education institutions students may enroll in developmental courses (Education Commission of the United States, 2015, para. 3). Studies of dual enrollment in Florida, New York City, and California found participation in dual enrollment courses taken by students in high school had a positive impact on that student going to college, remaining in college, earning more credits, and maintain a higher grade point average (Community College Research Center, 2012).

Research into the outcomes of Florida's dual enrollment program by Hoffman, Vargas, and Santos (2009) indicated students who had taken dual enrollment courses before entering college were "more likely to continue for a second semester and be enrolled two years after high school" (p. 53). In addition, Hoffman, Vargas, and Santos (2009) reported "former dual enrollees had higher GPAs than classmates with no dual enrollment experience and also had earned 15.1 more college credits on average than nonparticipants three years after high school" (p. 53).

Hoffman, Vargas, and Santos (2009) also looked at the results of dual enrollment students enrolled at the City University of New York (CUNY). The College Now dual enrollment program through CUNY showed that first-time freshman who had taken dual enrollment courses were more likely to enroll for a third semester and had higher average GPAs than their peers who had not participated in the College Now program. By the end of their first year of college, College Now students had also earned on average more 1.08 credit hours during the 2002/2003 year (Hoffman, Vargas, & Santos, 2009).

In the search for research that specifically tied dual enrollment with developmental mathematics students, little research on the effect of dual enrollment on underprepared students

and developmental mathematics programs was found. As stated by Karp, Calcagno, Hughes, Jeong, & Bailey (2007) “despite the popularity of dual enrollment, little is known about its effectiveness as a strategy for increasing students’ postsecondary attainment” (p. 2). One piece of research by Kim and Bragg (2008) found a significant positive relationship existed for students taking dual enrollment high school and being college ready in mathematics once in college. Pretlow and Wathington (2014) also noted success with dual enrollment programs in their study of the Virginia Community College System (VCCS), but also noted that students enrolled in dual enrollment courses are generally more academically prepared and motivated to succeed in post-secondary education. Pretlow and Wathington (2014) posit that success in higher education of dual enrollment students may in fact have nothing to do with taking dual enrollment courses but related to the preexisting academic preparation and motivation of students. With the lack of research in this area though, investigation of developmental mathematics and on how dual enrollment impacts the transition and integration of students into higher education is needed. Important information that may aid in implementing and designing dual enrollment courses could be revealed by looking specifically at students in developmental mathematics who have participated in dual enrollment courses and comparing those students to their student counterparts who have not had dual enrollment courses.

Acceleration Methods

Methods for accelerating students through developmental sequences used include fast-track courses that are shorter in duration than typical 16-week semester courses, self-paced modularized courses targeted towards specific areas in mathematics that students are underprepared, contextualizing pre-college level mathematics instruction into content areas, and mainstreaming students into college-level mathematics courses by offering traditional college-

level mathematics courses over a longer period of time such as two semesters or offering more support through tutoring or additional class periods for developmental students (Rutschow & Schneider, 2011). Eight-week, fast-track courses have the option of accelerating students through developmental mathematics programs because two-eight week courses can be taken back-to-back in one semester allowing the developmental mathematics student to complete one year of typical developmental mathematics courses in one semester (Jaggars, Hodara, Cho, & Xu, 2015). Typically fast-track course periods are longer in length so instructors have more time to “to diversify classroom activities and to encourage the development of stronger student–instructor relationships” (Edgecombe, 2011, p. 8). Research by Hern (2012) on 17 community colleges in California indicated fast-tracking courses had positive effects on students who place high in developmental course sequences with lower placed students showing no positive or negative effect in comparison to traditional 16 week courses.

Modularizing of developmental mathematics is based on mastery learning that allows courses to be targeted directly towards a student’s mathematics deficiencies and to be completed at a student’s own pace (Ariovich & Walker, 2014). “The hallmarks of this method are heavy reliance on computer-aided instruction (lessons, tutorials, quizzes, and exams) and breaking down mathematics concepts into separate modules for students to complete” (Ariovich & Walker, 2014, p. 46). A student can spend more time on mathematics concepts that are difficult while other portions of the modularized course that the student is already familiar with can be quickly completed.

Mainstreaming of developmental students into college-level mathematics courses has typically been used most often in four-year universities but have recently been experimented with in two-year colleges (Rutschow & Schneider, 2011). As stated by Hern (2012), “attrition is

high in developmental sequences, but more important, attrition is exponential. As students fall away at each level, the pool of continuing students gets smaller and smaller” (p.61). Information gathered by Bailey (2009) of 256, 672 community college students in the Achieving the Dream college network, which today includes over 200 colleges in 36 states (Achieving the Dream, Inc., 2016), of the students referred to developmental mathematics, only 13% completed the developmental mathematics sequence. With retention being an issue with many developmental mathematics students, mainstreaming them into college-level courses reduces the amount of exit points from school which in turn may reduce attrition and promote college completion.

As mentioned previously, developmental mathematics courses can also be accelerated through contextualization. Contextualization in academic disciplines or creating discipline specific learning communities in developmental mathematics courses (Rutschow & Schneider, 2011). Contextualization helps students accelerate through the required developmental mathematics by creating discipline specific, relevant mathematics courses that provide the academic skills required for college level mathematics courses (Edgecombe, 2011).

Acceleration through contextualization of developmental mathematics may involve moving the developmental mathematics courses from a mathematics department or developmental department into academic departments creating courses like business mathematics or technical mathematics (Hamilton, 2013).

Developmental mathematics courses may also incorporate learning communities or cohorts of students studying specific disciplines (Rutschow & Schneider, 2011). Learning communities can be incorporated into any type of developmental mathematics course or other courses. Tinto (1997) found that students in remedial courses that incorporate learning communities performed better than students in traditional remedial courses. Students beginning

at the same level in a sequence and who are interested in similar educational pursuits can be enrolled in identical courses at the same time to create a cohort which integrates students both academically and socially (Rutschow & Schneider, 2011).

California acceleration. In California, the California Acceleration Project was initiated in 2010 in an attempt to improve retention of developmental students in both mathematics and English programs. As noted in research by Bahr (2008) community colleges across California had exceptionally poor retention rates. In research by Hern (2012) one problem with remediation programs in colleges was that students often needed multiple semesters of coursework before being able to enroll what is considered a college level course. Research by Hern (2012) noted non-completion of remediation programs was attributed to students choosing not to enter into the recommended developmental courses and exiting the program at one of the multiple exit points allotted by an academic sequence that extends over multiple semesters (Hern, 2012). It was recognized that “students starting two levels below college mathematics or English face five exit points before completing the college-level course” (p. 61). Hern’s (2012) research included passing the first and second remedial course, passing the first college-level course, enrolling in the second remedial course, and enrolling in the first-college level course all as exit points that are considered problematic (Hern, 2012). Contrary to much research in developmental programs, the California Acceleration Project included enrolling and passing a college-level mathematics or English course, successful student completion of remediation. The California Acceleration Project recognized that redesign of multi-semester developmental programs into programs that required less time to finish and reduced the exit points between semesters could help improve the retention of students.

Chaffey College, a community college in Rancho Cucamonga, California, developed a bridge course at the beginning of the semester to help students accelerate the academic remediation of students beginning college (Hern, 2012). The program consisted of a three-week mathematics review for students placing into arithmetic, or four-levels below college algebra (Hern, 2012). After the bridge course, students were retested to assess if academic placement had improved (Hern, 2012). After retesting, most students placed as high as intermediate algebra, or one level below college algebra (Hern, 2012). In order to accommodate the bridge program, late-start sections of the remediation courses were developed so students were able to complete to the needed remedial courses (Hern, 2012). Developing late starting courses, accelerated the students through their required courses and allowed many to complete the needed remediation in in one semester (Hern, 2012).

Mainstreaming was a method of acceleration that was also used by community colleges participating in the California Acceleration Project. Different methods of mainstreaming for mathematics courses were used in the project such as placing developmental students directly into college level mathematics courses with added additional supports, such as small group class session classes taught by the same instructor, or placing students in college level courses using alternate methods of evaluation other than placement exams, such as high school coursework (Hern, 2012).

Although various methods of acceleration were used in the California Acceleration Project, seven of the colleges participating in the project offered pre-statistics courses that provided students a shorter path to college statistics than the typical developmental mathematics sequence (Hern, 2012). The pre-statistics courses in the seven project colleges used a variety of methods for presenting the curriculum including condensed methods that contextualized the

course in the statistics area while others employed various statistical software and online statistical materials (Hern, 2012). Students enrolling in accelerated statistics showed a 4.5 times rate increase in the completion of college-level mathematics in comparison to students with similar mathematics placement exam scores that followed the traditional developmental mathematics sequence (Hern, 2012).

Results of research on acceleration methods in the California Acceleration Project indicated that students taking accelerated developmental mathematics completed college level mathematics courses at 4.5 times the rate of students in traditional developmental sequences, when starting the developmental sequence at the same level (Hern, 2012). Results though indicated students placing into developmental mathematics at the lowest levels did not do as well in accelerated courses but did equivalent to students placing at the same level in traditional developmental mathematics courses (Hern, 2012). The results indicate accelerated programs can aid students in advancing developmental students through developmental sequences.

Texas developmental program redesign. In 2008, the Texas Higher Education Coordinating Board (THECB) funded nine higher education institutions (five community colleges and four universities) to implement newly designed and structured developmental mathematics programs that used new curriculum designs and instructional strategies (Booth, et al., 2014). Although each college and university could use a number of different components in modifying their developmental mathematics programs that included student support services, targeted professional development of faculty, collaborative learning models, directed student counseling and advising, and other instructional and curriculum methods, two common components for acceleration that were used were fast-tracking, or condensing the traditional semester long developmental mathematics courses and targeted advising services to aid students

with accelerated learning (Booth, et al., 2014). As previously mentioned, fast-tracking of developmental courses adjusts the typical semester long course into a shorter duration courses less than a semester in length (Rutschow & Schneider, 2011). In the Texas study, the curriculum of a typical 16-week developmental mathematics course was condensed into eight or 12-week courses. In addition to this condensing and accelerating of courses, the institutions in this group also implemented modularized, self-paced learning format that included options for blended course delivery (Booth, et al., 2014).

Results of a qualitative investigation of the program following two years in operation indicated accelerated programs in developmental mathematics aided in getting students to a mathematics level that is needed to enroll in college level courses, although it appeared as though self-motivation was a strong determining factor in whether this target was achieved (Booth, et al., 2014). Contrary to Hern's (2012) research, results from the Texas study indicated lower achieving students did not perform well in these accelerated programs and were better supported in their mathematics development in traditional developmental mathematics courses (Booth, et al., 2014).

Targeted approaches were also used to accelerate the students through developmental sequences by incorporating contextualization methods. These targeted methods included training for advisors to be specific to developmental mathematics, the inclusion of summer bridge programs and other student developmental courses that help increase student college readiness, guided study courses, and student monitoring/early warning systems, all which appeared to have positive effects on developmental students (Booth, et al., 2014). Although the qualitative analysis of the research indicated the developmental programs in Texas supported students, quantitative data collected during the initial two years of the program indicated student

developmental success dropped during the second year of the program in four of the schools. For example UT-Austin went from a student success rate of 92% during the first year of the modified developmental program to a success rate of 62% in the second year (Booth, et al., 2014). Why there was a drop in students completing accelerated programs in some of the schools is unknown. Five schools in the program though showed increases in pass rates for students across the two years of the study (Booth, et al., 2014).

Technology Enhancement of Developmental Mathematics Initiatives

One of the significant changes to developmental mathematics courses, involves the environment of the program and the method of course delivery that is incorporated with the developmental mathematics design modifications. Incorporating computer technology in developmental mathematics can be categorized as an acceleration method (Boylan & Saxon, 1999; Epper & Baker, 2009) because it provides a means for presenting the curriculum and instruction to students that can be accessed at any time and worked through at their own pace, but computers can also be an enhancement tools that simply provides a means for presenting assignments and/or assessments, as well as a tool for increasing access to higher education for learners at a distance.

Waycaster (2001) research on developmental programs indicated developmental student attendance rates and passing percentages are much lower than traditional students. The incorporation of computer technology to develop hybrid and online courses helps reduce or eliminate the need for students to travel to the campus for courses. Considering that attendance rates of developmental students range from 56-81% (Waycaster, 2001), creating courses that reduce or eliminate attendance on campus could play a role in helping students complete developmental mathematics sequences. Creating either blended or online developmental

mathematics course in place of, or along with traditional courses is an additional method of supporting students in schools. Hybrid and online courses offer a pathway to education for nontraditional students in higher education by allowing for students with external commitments to be able to take courses.

Web-based homework. Holt, Holt, and Lumadue (2012) completed a mixed-methods study of university students enrolled in a developmental mathematics course at the Intermediate Algebra level that used web-based homework system. Holt, Holt, and Lumadue (2012) were hoping to gain an understanding of how the “perceptions of developmental mathematics students towards the MyMathematicsLab web-based homework program” (p. 6). The research employed a cross-sectional survey design that “used both ranked questions and open-ended prompts that enabled a more meaningful examination of student perceptions” (p.6). Holt, Holt, and Lumadue (2012) hoped to obtain information on the students comfort level in using web-based programs for homework, how do the homework affect student understanding of mathematics, what parts seem to be beneficial, and how well does the web-based homework supplement classroom instruction.

One important point that the authors make is that the majority of students who are targeted with these web-based homework, developmental mathematics programs are adept to learning with technology (Holt, Holt, & Lumadue, 2012). Technology is an ever increasing medium for the transfer of knowledge to students, and the student respondents reflected this notion in that they responded they were comfortable using the system, found it user friendly, and preferred the computer-based homework over traditional homework (Holt, Holt, & Lumadue, 2012). Some of the respondents indicated that their experience with technology made it easy to trick the system in to providing the correct answer and because of this, they readily admitted that

mastering the mathematics concepts in the homework may not be occurring (Holt, Holt, & Lumadue, 2012). About a third of the students expressed frustration with the web-based homework system because the system was sensitive to formatting and syntax issues that made submittal of answers difficult (Holt, Holt, & Lumadue, 2012). The research reported that “students felt frustration in converting their answers to a form acceptable to the MyMathematicsLab program” (Holt, Holt, & Lumadue, 2012, p. 14).

In addition, many of the students surveyed, although they were believed by the researchers to be computer savvy, indicated they forgot to do homework because it was not written down on paper (Holt, Holt, & Lumadue, 2012). Many also indicated that they did not use the program to its full potential by not using all of the components available in completing their homework (Holt, Holt, & Lumadue, 2012). Not using all of the components available to them may have had negative effect on the student outcomes and perceptions of the system.

The research indicated that the students demonstrated an increased understanding of mathematics after using the computer system in their homework. Students felt having time to work at their own pace was a benefit because they could work through problems slowly and deliberately, and revisit topics when needed (Holt, Holt, & Lumadue, 2012). The research supported the use of computer, or web-based systems in self-paced developmental mathematics courses. Essentially, courses designed using web-based computer systems for homework are traditionally presented developmental mathematics courses enhanced by self-paced learning.

Computer-based instruction. Computers have expanded in their use in schools beyond the occasional laboratory or classroom application. With the increase in availability and use of technology in academia, a recent implementation has been a change from the traditional lecture-

based course to computer-based instruction, where the computer becomes the curriculum delivery system (Ariovich & Walker, 2014; Spradlin & Ackerman, 2012).

Several developmental mathematics programs in higher education institutions have changed their traditional lecture-based programs into computer-based instruction programs intended to accelerate students through the required courses (Ariovich & Walker, 2014).

Computer-based developmental mathematics replaces the traditional teacher guided instruction with computer instruction. Computers with specialized software replace the traditional lecture with videos and all homework, quizzes, and exams are done using the computer while the instructor takes on a role of tutor. In addition, these new systems provide the student with self-paced learning using a modularized structure that breaks down the traditional semester into shorter, competency-based units (Rutschow & Schneider, 2011). The idea being that students who excel with the system move faster through the coursework and those who struggle can spend additional time on topics in comparison to a traditional lecture-based mathematics classroom.

Research in computer-based developmental mathematics courses has been extensively investigated in research and often indicates mixed outcomes of these programs (Ashby, Sadera, & McNary, 2011; Ariovich & Walker, 2014; Hodara, M. & Columbia University, 2011; Holt, Holt, & Lumadue, 2012; Ye & Herron, 2010; Zavarella & Ignash, 2009). Much of the research in computer-based developmental mathematics programs relates to student attitudes, sex, race, culture, and ethnicity, and how these characteristics impact course outcomes programs (Ashby, Sadera, & McNary, 2011; Ariovich & Walker, 2014; Hodara & Columbia University, 2011; Holt, Holt, & Lumadue, 2012; Ye & Herron, 2010; Zavarella & Ignash, 2009). This current study investigated whether computer-based developmental mathematics programs support

student retention by increasing course completion and degree attainment rates, which in turn supports student migration into college-level mathematics courses and four-year universities.

A computer-based modular developmental mathematics initiative at a large suburban community college with over 13,300 ethnically and culturally diverse credit students was researched by Ariovich and Walker (2014) using a mixed-methods approach. Rather than following a traditional three semester course sequence, the modularized computer-based developmental mathematics program was sequenced into 14, self-paced modules that were identical in curriculum to the traditional developmental course sequence. With the course being self-paced, students could complete the entire developmental mathematics sequence in one semester depending on their mastery of the mathematics concepts. The research of Ariovich & Walker (2014) used statistical methods to compare the success of students based on passing rates in the modular program versus traditional programs, and then interviewed five focus groups, one of faculty and four of students, to determine faculty and student opinion of the modular programs ability to teach mastery of the mathematics concepts.

The quantitative investigations by Ariovich & Walker (2014) indicated students in computer-based modularized developmental mathematics at the lowest levels struggle at first and don't perform as well as students in traditional developmental mathematics courses. Ariovich and Walker (2014) though found as computer-based course students move into higher mathematics levels, their pass rates improve, indicating "those who pass seem more likely to learn and retain the concepts and skills needed to succeed in higher level developmental mathematics courses" (p. 48). Although pass rates for modular course students improved in higher mathematics levels, traditional course students still passed at a higher percentage (Ariovich & Walker, 2014). To further evaluate the two developmental mathematics methods,

traditional course pass rates of below the B level were eliminated so to compare to the modular pass rates where A or B level is required to indicate student mastery (Ariovich & Walker, 2014). The pass rates for traditional mathematics courses still remained higher even when eliminating the C level students (Ariovich & Walker, 2014). Even with the difference in pass rates, the authors contend that the results are mixed because the study was preliminary and did not contain longitudinal data (Ariovich & Walker, 2014).

The qualitative portion of Ariovich and Walker's (2014) research appeared to show that instructors believed the computer-aided courses provided better mastery learning than traditional. The instructors believed the modules demanded more of the students and because the students set their learning pace, they could better master their skills (Ariovich & Walker, 2014). In comparison to the instructors, students seemed to be indifferent about mastery learning and felt the modules increased their work and slowed their progress (Ariovich & Walker, 2014). Students favored the modular system because they could work at their own pace, they did not have to finish a semester equivalent of work in one semester, and if they did not finish, they could begin the next semester where they left off the previous semester (Ariovich & Walker, 2014). The research also suggests though that the majority of students were uncomfortable with the computer systems and that instructors were better at explaining problems and ideas. The research provides some ideas on how to improve modular course design.

Ye and Herron (2010) conducted a three semester long mixed-methods study comparing computer-based mathematics with traditional mathematics courses. Ye and Herron (2010) compared the learning outcomes of students in both types of courses, the student attitudes regarding the courses, and compared the results of final exams to hours on task in the computer-based mathematics course.

The quantitative research showed no difference in final exam scores in computer-based mathematics and traditional courses (Ye & Herron, 2010). Student confidence about their mathematics competence and learning was also equal in both types of courses (Ye & Herron, 2010). Final exam scores and hours spent in the mathematics lab on task using with the computer system showed a direct correlation in two of the three semesters (Ye & Herron, 2010).

The qualitative research indicated the computer-based mathematics students had a slightly better attitude toward mathematics and were more independent in their learning (Ye & Herron, 2010). The results also showed students in the computer-based mathematics course were more confident in their abilities (Ye & Herron, 2010). Instructors that participated in the research saw the computer-based mathematics instruction as a positive method for teaching mathematics and a benefit in helping the students learn mathematics concepts more effectively (Ye & Herron, 2010).

Hodara and the Community College Research Center (CCRC) at Columbia University (2011) reviewed thirteen studies completed on computer-based developmental mathematics programs at community colleges and concluded that none of the research was rigorous enough to bare any meaningful information regarding the benefits or disadvantages of these computer-based mathematics courses (Hodara & Columbia University, 2011). Results that were identified showed no discernable differences between students learning in computer-based or traditional mathematics courses (Hodara & Columbia University, 2011). The computer-based mathematics showed benefits and promise, but the authors indicated more research needs to be completed to further evaluate computer-based mathematics programs (Hodara & Columbia University, 2011).

Online and hybrid courses. Quantitative research conducted by Ashby, Sadera, and McNary (2011) on developmental students at a community college taking intermediate algebra in different course formats found “distance-based and blended students performed worse than the traditional face-to-face developmental mathematics students when not taking attrition into account, however considering only students who completed the course, face-to-face students performed worse” (p. 138). After taking attrition into account, results from Ashby, Sadera, and McNary’s (2011) research indicate traditional developmental mathematics averaged 71.6% in the course, hybrid students averaged 73.1%, and online students averaged 78.1% indicating hybrid and online courses increase mathematics learning. Ashby, Sadera, and McNary’s (2011) found the results of their research inconclusive apparently due to the role attrition played in the investigation.

Zavarella and Ignash (2009) completed a quantitative study of computer-based mathematics courses and their retention rates. The study revealed students enrolled in computer-based mathematics courses are more likely to not complete the course versus those in traditional mathematics courses, especially those in developmental courses in community colleges (Zavarella & Ignash, 2009). As the authors pointed out, much research has been conducted that shows computer-based mathematics courses and traditional mathematics courses are both as effective at student achievement, but little research has been conducted on the reason why withdrawal rates are higher in computer-based courses (Zavarella & Ignash, 2009). One factor that may impact retention in computer-based programs that require a student have personal motivation to complete work may be related to the type of student who most often enrolls in community colleges. The average age of the community college student is 28 years old, with the median age being 24 years, 14% are over 40 years old, 17% are single parents, 36% are first

generation college students, 7% are non-U.S. citizens, 4% are veterans, and 12% are students with disabilities. In addition, 22% of full-time students and 41% of part-time students are employed full-time while 44% of full-time and 32% of part-time students are employed part-time (American Association of Community Colleges, 2016a). Courses that require abundant time commitments outside of the classroom may impact the outcome of the typical community college student.

Zavarella and Ignash's (2009) study took place at a large multi-campus urban community college in Florida. Three groups of developmental mathematics students were studied, a traditional course group, a hybrid group, and a completely online group (Zavarella & Ignash, 2009). The authors looked at gender, race/ethnicity, age, and the learning styles as part of the study. The groups were predominately female, African American or Hispanic, under 25 years old, and considered collaborative or participant in their learning style (Zavarella & Ignash, 2009). Results of the study showed higher withdrawal rates in the hybrid and online courses in comparison to the traditional course. Their research showed students who enrolled in a course based on perceived learning needs were more likely to not finish a course (Zavarella & Ignash, 2009). Placement tests scores were a non-factor, students with similar scores on placement tests were more likely to complete a traditional course than those in hybrid or online courses (Zavarella & Ignash, 2009).

Zavarella & Ignash (2009) concluded,

(a.) students enrolled in either a distance learning or hybrid developmental mathematics course were twice as likely to withdraw from the course as those who enrolled in a lecture-based course; (b.) students who enrolled in a hybrid, distance, or lecture-based developmental mathematics course for personal reasons were more likely to complete the

course as compared to those who enrolled based on their perceived learning needs; and (c.) student learning styles and placement test scores did not seem to affect their completion status in a developmental mathematics course delivered via any of the three instructional formats (p. 8).

The authors believe their research suggests that developmental students may not be cognizant of their best learning styles, may not understand the demand of hybrid or online courses, and may not be aware of the time commitments associated with hybrid and online learning (Zavarella & Ignash, 2009). Tutoring and instructor availability is believed by the authors to be a significant factor in retaining students in computer-based developmental mathematics courses (Zavarella & Ignash, 2009). The authors believe computer-based developmental mathematics courses have positives for many students but for those who are unfamiliar with computer-based mathematics, intervention is probably needed to help retain those students who are most likely to withdraw (Zavarella & Ignash, 2009). “Institutions should increase the communication between themselves and their students to gain a better understanding of their issues and concerns” (Zavarella & Ignash, 2009, p. 12).

Influence of rural residency in computer-based courses. Many rural students suffer from a lack of modern technological infrastructure to support online learning (Cejda, 2010). Similar to the digital divide in education that is related to socio-economic status, rural students may also suffer from a digital divide created by the lack of developed infrastructure in remote areas (Cejda, 2010; Leist & Travis, 2010). As stated by Cejda (2010) “broadband connection in rural homes lags 19% behind that of urban homes and 22% behind that of suburban homes” (p. 13).

Because developmental courses are targeted towards students who are underprepared for college level courses, and many rural community college students are underprepared, rural college students may often test into developmental courses. In addition, their geographical location, coupled by characteristics inherent in many nontraditional students, hybrid/blended and online developmental courses may be their best option in pursuing studies in higher education. Recent data indicates an estimated 5.5 to 7 million U.S. college students are taking at least one online course, with the majority being community college students (Allen and Seaman, 2011, 2013; National Center for Education Statistics, 2013). For students living in rural areas, online courses may be an appealing alternative to commuting to campus.

Research has shown rural students may suffer academically due to the lack of adequate technological infrastructure in rural areas (Cejda, 2010; Leist & Travis, 2010). The digital barrier created by the lack of technological infrastructure may impact the integration of students into higher education. Lower grades and retention rates in comparison to students in who are generally well supported by technological infrastructure in non-rural areas may be an indicator technology creating a barrier to integration to higher education.

Summary

In recent years, much of the attention in higher education has been devoted to the redesign of developmental mathematics programs because of the increasing percentage of students entering higher education who are underprepared for college-level mathematics courses (Ariovich & Walker, 2014; Bonham & Boylan, 2012; Brothen & Wambach, 2012). One reason that redesign has been an emphasis in developmental mathematics programs recently is because traditionally, the objective of developmental mathematics has been remediation (Brothen & Wambach, 2012) not student academic development. Developmental mathematics in the past

was “traditionally organized and taught, as an obstacle to student success rather than as a support” to students. (Venezia & Hughes, 2013, p. 38). Although students who lack college-level mathematics skills often “are motivated to overcome the barriers that stand between them and their educational goals, many more fail to engage this sometimes daunting task” (Brothen & Wambach, 2012, p. 34) when faced with the reality of multiple semesters of non-credit courses. As Hern (2012) emphasized, although remedial programs were designed to strengthen student skills and help them achieve their goals, remedial courses are often where underprepared students lose their motivation to continue their academic pursuits.

The redesign of developmental mathematics programs has targeted both curriculum and the delivery of the instruction (Ariovich & Walker, 2014) in order to change these remedial programs from obstacles to pathways through higher education for students who are underprepared for college and universities studies. With new advances in educational technology in recent years, technology driven systems designed for both aiding and providing instruction (Ariovich & Walker, 2014), along with the readjustment of the mathematics curriculum based on the concepts of avoidance, acceleration, and contextualization (Booth, et al., 2014; Brothen & Wambach, 2012; Hern, 2012; Hodara & Columbia University, 2011; Rutschow & Schneider, 2011), many developmental mathematics programs in higher education have seen substantial changes in their curriculum structure and delivery methods.

Research on the recent reforms in developmental mathematics have shown mixed results on their benefits to students. The research into the effectiveness of these programs is difficult to relate to one specific strategy because much of the research involves programs that implement multiple curriculum and instructional strategies (Rutschow & Schneider, 2011). Developmental mathematics reforms typically involve numerous curriculum reforms which makes isolating the

effects of specific strategies difficult (Hamilton, McCaffrey, Stecheer, Klein, Robyn, & Bugliari, 2003). A single variable responsible for a positive or negative outcome in developmental mathematics program may be misinterpreted when evaluating a program, if for instance, multiple acceleration strategies are coupled with instruction via computer-based/enhanced instruction. To effectively evaluate a specific developmental mathematics curriculum or instruction strategy, curriculum types and modes of instruction need to be isolated and analyzed to determine their impact on student learning.

CHAPTER III: RESEARCH METHODOLOGY

Theoretical Framework

The theoretical framework in this research is based on concepts in Tinto's (1993) *Longitudinal Model of Individual Departure from Institutions of Higher Education*, which is a modification of Tinto's *Longitudinal Model of Dropout* (Tinto, 1975). Tinto's theory asserts that for a student to persist in higher education they must be able to integrate into the social and academic communities of higher education. The theory contends that student commitment to higher education is strongly influenced by individual, social, economic, and cultural characteristics, as well as academic experience (Tinto, 1975, 1993, 2006). The integration into higher education is a longitudinal process that is influenced by student participation in the social and academic communities provided by the institution (Khuong, 2014). Essentially, a student has characteristics that influence their commitment to higher education but an institution influences this commitment through academic practices and administrative policies that create a sense of belonging and increase academic aptitude.

Through a positivist lens, Tinto's *Longitudinal Model of Individual Departure from Institutions of Higher Education* will be used as a basis for investigating the effect of dual enrollment and rurally situated students in developmental mathematics courses in a community college in the midwest that uses computer-based instruction. According to Creswell (2014), the researcher, through the post-positivist lens, develops knowledge through observation and/or by interpreting numeric data that is then used to determine if the observed behaviors or collected data appears to effect outcomes. The research will evaluate whether dual enrollment, rural residency and online instruction, and instructional methods in developmental mathematics courses appears to have an effect on student course grades, course completion, developmental

mathematics sequence completion, degree/certification attainment, or transfer to a four-year university.

Although Tinto (1975, 1993) did not specifically discuss the influence of technology use in the classroom on student integration, Tinto emphasized the importance of faculty actions in the classroom being critical to increasing student retention (Tinto, 2006). In addition, the majority of Tinto's (1993) model is based on four-year universities rather than two-year colleges. Tinto's (1993) model addresses the differences associated with non-residential and two-year colleges. In commuter colleges, such as the community college being researched in this study, there are finite opportunities for students to become involved in social communities so the classroom is the primary means of integrating a student to higher academia. Tinto (1993) indicates that emphasis in commuter colleges needs to be in "1) the construction of classroom communities; 2) the strengthening of the student and faculty communities within the college; 3) bridging the gap between the world of college and external communities; and 4) the timely provision of services to students" (p. 192). It is believed that student/faculty interactions and student/student interactions in the classroom strengthen commitment to persist in school (Tinto, 1993, 1997, 2006; Tinto, Russo, & Kadel, 1994). Reducing both faculty and peer interactions in a computer-based course therefore, according to Tinto's (1993) model, may impact student integration, and may therefore influence student degree/certification attainment and transfer to four-year university studies.

Research Questions

For purposes of researching the developmental mathematics program at the community college being researched, three research questions will be addressed.

RQ 1: Are students who have taken dual enrollment courses in high school more academically successful in a computer-based developmental mathematics courses and programs than students who have not had dual enrollment courses?

RQ 2: Are students who live in rural areas academically less successful in computer-based developmental mathematics than students who live in non-rural areas?

RQ 3: Does the curriculum and instruction delivery method used in developmental mathematics have a significant relationship with successful course completion and degree attainment in academic programs of study?

Hypotheses

As stated by Creswell (2012), “hypotheses are statements in quantitative research in which the investigator makes a prediction or a conjecture about the outcome of a relationship among attributes or characteristics” (p.111). Each hypothesis is based on information gathered from past research on dual enrollment, location characteristics that impact rural students, computer-based/enhanced developmental mathematics, and distance education. The following hypotheses for this research study are based on the research questions for this study. Hypotheses are numbered according to research questions and broken down to sub-hypotheses.

Hypothesis 1

Null Hypothesis 1a

H₀ – There is no difference in overall course grades for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Research Hypothesis 1a

H_a – There is a difference in overall course grades for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Null Hypothesis 1b

H₀ – There is no difference in course completion rates for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Research Hypothesis 1b

H_a – There is a difference in course completion rates for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Null Hypothesis 1c

H₀ – There is no difference in degree attainment for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Research Hypothesis 1c

H_a – There is a difference in degree attainment for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Hypothesis 2

Null Hypothesis 2a

H_o – Course completion rates for students who reside in rural areas will not differ for computer-based developmental mathematics students in comparison to those who reside in non-rural locations.

Research Hypothesis 2a

H_a – Course completion rates for students who reside in rural areas will differ for computer-based developmental mathematics students in comparison to those who reside in non-rural locations.

Null Hypothesis 2b

H_o – Degree attainment rates for students who reside in rural areas, and who take at least one computer-based developmental course online, will not differ from students who do not reside in rural areas, and who take at least one computer-based developmental math course online.

Research Hypothesis 2b

H_a – Degree attainment rates for students who reside in rural areas, who take at least one computer-based developmental course online, will differ from students who do not reside in rural areas who take at least one computer-based developmental math course online.

Hypothesis 3

Null Hypothesis 3a

H₀ – Course completion rate for students in computer-based developmental mathematics courses do not differ from students in traditional developmental mathematics courses.

Research Hypothesis 3a

H_a – Course completion rate for students in computer-based developmental mathematics courses do not differ from students in traditional developmental mathematics courses.

Null Hypothesis 3b

H₀ – Degree attainment rates for students in computer-based developmental mathematics courses do not differ from students in traditional developmental mathematics courses.

Research Hypothesis 3b

H_a – Degree attainment rates for students in computer-based developmental mathematics courses do differ from students in traditional developmental mathematics courses.

Null Hypothesis 3c

H₀ – Course completion rates for students in online computer-based developmental mathematics courses do not differ from students in on-campus computer-based developmental mathematics courses.

Research Hypothesis 3c

H_a – Course completion rates for students in online computer-based developmental mathematics courses do differ from students in on-campus computer-based developmental mathematics courses.

Research Setting

Demographic Data

The community college being researched is Heartland Community College. The college is located in central Illinois within a moderately-sized metropolitan area, in a rural community college district. Demographic data summarized by the National Center for Education Statistics (2015-2016) for Heartland Community College is summarized in Table 1 below.

Table 1

National Center for Education Statistics Demographic Data for Research Location, 2015-2016

	Percent	Total
Gender		
Male	44.8	2374
Female	55.2	2924
Ethnicity		
White	69.7	3693
Black or African American	12.0	636
Hispanic/Latino(a)	6.9	366
Asian	3.1	164
American Indian/Alaskan Native	0.1	5
Native Hawaiian/Pacific Islander	0.1	5
Multiethnic	3.6	191
Non-resident alien	0.4	21
Unknown	4.1	217
Total Enrollments	100	5298

Developmental Mathematics Program Data

Heartland Community College underwent developmental mathematics redesign in 2011. The college converted its traditional, multi-semester developmental mathematics program into a modularized, computer-based developmental mathematics program. Although the modular

format is considered a traditional class in the sense that students are expected to be on campus multiple days a week, the classes are held in a laboratory setting. The course content is delivered via a computer-program through a computer workstation. The laboratory is monitored by full-time and part-time mathematics instructors and mathematics tutors who help students with their work when students have questions. Student progress and grades are tracked by the instructor of record for each student with feedback provided through email. Coursework can be completed both on-campus and off-campus through the Internet, but summative assessment of course modules is required to be completed on campus in a dedicated developmental mathematics testing center.

The modular system of presenting the course material divides the entire course into a set of modules, each containing video lecture, video demonstration, practice exercises, required exercises, and practice quizzes (Mary F., personal communication, October 23, 2014). Each module represents a section of one course and for students to advance to new modules, a quiz over the module scoring at a minimum of 75% must be completed to move on to the next module. Twelve modules make up a milestone and one milestone is the equivalent to a one-semester traditional developmental mathematics course. A final exam is taken at the end of a milestone and a score of 80% must be obtained for successful completion of the milestone. Once a student completes a milestone they may proceed onto the next milestone and complete more than one semesters worth of work in a 16-week period. In addition, a student who completes a milestone at any point in the semester can choose to stop at that point because one milestone is equal to one semester of developmental work. A student must complete at least one milestone in one semester to receive a passing grade of P for the course. If a student does not finish a milestone, they do not fail the course but are expected to continue where they left on in the

following semester. The redesign of the program to a computer-based modular format reduces the number of students failing courses but failures and withdrawals are still numerous.

Data Acquisition

Student academic data has been collected and recorded by Heartland Community College since its inception 1991. Student academic data related to the variables in this research were retrieved from academic databases at the college by personnel of the Department of Institutional Research, cleaned of any personal identifiable data, reclassified by these same personnel by data attribute guidelines provided by the researcher, and delivered electronically to the researcher. Institutional Review Board protocols were followed both at the researcher's university and Heartland Community College. Findings by both institutions indicated that the research was non-human subjects research and did not need approval to be completed.

The academic data associated with developmental mathematics courses at Heartland Community College is not comparable across all years the college has been in existence. Since the inception of the college in 1991, developmental mathematics courses, along with other courses, have seen curriculum changes which in turn changed the course numbering system. For this reason, data acquired from the early 1990's is not relatable to data of recent years, and therefore it was excluded from this study. Although instructional and course delivery methods have changed since the 2008, the course curriculum associated with a specific course number is identical.

Prior to the fall semester of 2011, developmental mathematics was taught using traditional methods. The courses were taught face-to-face and spanned multiple semesters. In the Fall 2012 semester, with the aid of a grant from the Bill and Melinda Gates Foundation, a computer-based modular developmental mathematics program was implemented (personal

correspondence, Mary F., 2014). At that time, instructional methods changed but course content remained identical. Although course numbers changed and instruction became computer-based, the new courses were equivalent to previous courses of recent years.

The data acquired for analysis needed to be data that was relatable across traditional and computer-based sequences. As stated previously, academic data from the developmental mathematics program is not related across all years due to changes in course curriculum and program structure. In discussions with the Executive Director of Institutional Research at the college of study, it was recommended that student data prior to the early 2000's not be used because the data from those earlier courses is nearly impossible to relate to course data from more recent years. So that the data was relatable across several years, data from Fall 2008 through Spring 2016 semesters was used in the study.

In 2014, the college conducted an analysis of the historical academic data from all developmental mathematics courses ever offered at the college. This research was conducted by the Department of Institutional Research at the college. The analysis of the developmental mathematics program was compiled in a report that was submitted for review at an academic organization that certifies developmental mathematics programs. The data from this research includes information related to the majority of variables in this study, in much of the data was therefore easily retrievable.

Student data for dual enrollment and rural residency designation is not part of the developmental mathematics data controlled by the Department of Institutional Research at Heartland Community College. Personnel of the Department of Institutional Research requested the data from Student Records at the college and compiled with the developmental mathematics data by personnel of the college's Institutional Research Department. Student records data is

categorized by academic term and includes academic, demographic, and secondary school data for all students in college developmental mathematics courses that was needed for this study.

Study Sample

From the population of students at the community college being researched, a longitudinal sample of students consisting of all developmental mathematics students from both traditional and computer-based courses, from a period of Fall 2008 through Spring 2016, was used in the statistical analysis. The original data file supplied to the researcher by the college contained student records from both college-level and developmental mathematics. After the college-level mathematics records were removed, the remaining sample included 26546 records, with 11229 individual student records for both traditional and computer-based developmental mathematics. Non-probability sampling insures that the mathematics courses in both the traditional and computer-based courses are consistent in their curriculum for each course number designation.

Methodology

Developmental mathematics programs in higher education have seen many changes to the curriculum and instruction in recent years. The redesigned programs were developed to improve student retention and completion of programs while at the same time improving mathematics concept mastery. Although research has been completed by many scholars on these newer developmental mathematics programs, much of the research is limited (Rutschow & Schneider, 2011). In many of the newly designed developmental mathematics programs, multiple methods of supporting students are implemented, and much of the research that shows positive outcomes for these programs (Booth, et al., 2014), have not evaluated specific student supports. Research is needed in higher education developmental mathematics programs to

determine if one or several of the newer developmental methods can be individually correlated to positive outcomes for students (Jaggars, Hodara, Cho, & Xu, 2015; Rutschow & Schneider, 2011). Research may show support for students in developmental mathematics programs using a variety of support methods but a closer look at individual parts of the program that examines each individual piece of support needs more investigation. An analysis of individual developmental mathematics student supports is needed to determine if individual, or a combination of avoidance, acceleration, and contextualization support methods are providing a benefit to students.

The purpose of this research was to complete a quantitative investigation of the developmental mathematics curriculum in a computer-based modular developmental mathematics program at a community college in central Illinois. Computer-based modular developmental mathematics lessens the amount of instructor/student and student/student interaction and turns the traditional developmental mathematics classroom into a computer laboratory. Theoretically, the limiting of classroom interactions during the first year in a post-secondary institution that primarily serves commuter students, will negatively impact student integration into the higher education institution and diminish persistence (Tinto, 1975, 1993, 1997, 1999, 2006). A theoretical approach based on the ideas of Tinto will be used to investigate the significance of various aspects of computer-based developmental mathematics on persistence of students in community college. The significance of in-class and online computer-based instruction, dual enrollment courses in high school, and the role of rural internet connectivity in computer-based instruction was investigated to see if there is a relationship between these variables and student success in terms of grades, time in school, course completion, and degree/certificate.

Research Variables

As stated by Creswell (2012), “In educational research, your objective may be to relate variables rather than manipulate the independent variable, as in an experiment. If so, your design is correlational research” (p. 339). For purposes of this research, a predictive correlational quantitative study of a computer-based developmental mathematics program at a community college in central Illinois was completed. For this study, the independent variables of impact of dual enrollment (yes or no), student residency (rural or non-rural), course delivery (online or traditional), and course type (traditional or computer-based) was analyzed with the dependent variables of developmental course grades (pass or no-pass), course completion (yes or no), and degree/certification (yes or no). The independent variables and dependent variables were analyzed as categorical, nominal variables coded for use in IBM® SPSS® Statistics.

Because grading in traditional courses was based on the typical A through F grading schema, the grades were reclassified as pass (A, B, or C) and not pass (D or F) so they could be as near to equivalent as possible with the computer-based developmental mathematics course where a minimum of a C+ level (75%) grade must be earned to pass the course. Reclassifying grades to equivalent categorical dependent variables allowed for Pearson chi-square testing.

Along with the independent and dependent variables of interest, control variables were coded for analysis in IBM® SPSS® Statistics. Control variables are extra variables that can influence the dependent variable. For example, age may positively influence the final grades in an online course because adults tend to be more self-motivated in their learning. Therefore, age of a student has an influencing effect if one is trying to analyze the relationship between gender and final grades in an online course. If analysis of gender and final grades shows that males on average do better in the online course, and all the males in the course are older than 30 years, age

may actually be more significant than gender on the final grade. The effect of the control variables in statistical analysis is important so the influence of those variables can be evaluated.

The control variables in this study are age, gender, ethnicity, year in school course taken, and ACT mathematics exam scores. Each control variable was controlled through statistical procedures (Creswell, 2012). Control variables were included in subsequent analyses with the variables of concern to determine how they appeared to impact the dependent variables. Outcomes with and without control variables were used to determine the effect of the control variables. The independent and control variables, along with their level of measurement are listed in Table 2 below. Following Table 2, Table 3 lists the dependent variables, along with their level of measurement.

Table 2

Independent Variables Analyzed

Variables	Variable Code	Level of Measurement
Independent Variables		
Dual Enrollment	Dual Enrollment Taken = 1 No Dual Enrollment Taken = 2	Nominal
Student Residency	Non-rural = 1 Rural = 2 Undefined = 3	Nominal
Course Delivery Method	Not Online = 1 Online = 2	Nominal
Age	15 – 87	Ordinal
Gender	Male = 1 Female = 2 Undeclared = 3	Nominal
Ethnicity	White = 1 Black = 2 Hispanic = 3 Other = 4 (Asian, American Indian or Pacific Islander, Non-resident Alien, Multi-ethnic)	Nominal
Year in School Developmental Mathematics Course Taken	0 to 1 year = 1 1 to 2 years = 2 2 or more years = 3	Nominal
ACT Mathematics Score	9 – 30	Ordinal

Table 3

Dependent Variables Analyzed

Variables	Variable Code	Level of Measurement
Dependent Variables		
Course Grade	Pass = 1 (A, B, C, Pass) No Pass = 2 (D, F, No Pass)	Nominal
Course Completion	Pass = 1 (A, B, C, Pass) No Pass = 2 (D, F, No Pass, Withdrawn)	Nominal
Degree Attainment	Degree = 1 (Associate in Arts, Associate in Applied Science, Associate in Engineering Science, Associate in Science) No Degree = 2	Nominal

Data Analysis

The independent and dependent variables were analyzed using cross-tabulation bi-variate statistical analysis, independent samples *t*-tests, and binary logistic regression. Pearson’s chi-square test (Plackett, 1983) was used to test for independence between the independent variables and dependent variables. Results were then used to determine the level of associations between the independent and dependent variables. Statistical significance was assessed through the proper statistical test of significance. When significance was found in the analysis of the variables at the < .05 level, effect size was determined using the phi coefficient and Cramer’s V.

Pearson’s chi-square was used to analyze the control variables of age, gender, ethnicity, year in school course taken, and ACT mathematics exam scores to contributing effect of the control variable on the independent and dependent variables. “The chi-square statistic is used to

show whether or not there is a relationship between two categorical variables” (Kremelberg, 2011, p. 120). If a significant association between independent and dependent variables was evidenced, the association was used to determine if statistical analysis with the addition of controls was needed. Analysis of the control variables, when appropriate, was added to the analysis of the research variables so the influence of the control variables could be evaluated. These control variables were evaluated because their influence, if any, is inseparable from the independent variables of interest.

Analytical results from analysis of the control variables revealed if student age, gender, ethnicity, year in school course taken, and ACT mathematics exam scores had an influence on course grades, course completion, and degree attainment. Establishing the influence associated with these control variables was necessary to indicate any possible contribution these variables had on the independent variables of interest.

Summary

In this study, several years of academic and student records from Heartland Community College in Normal, Illinois, were obtained for students who had participated in developmental mathematics courses between Fall 2008 and Spring 2016 semesters. Data about student academic needs, desires, external influences, and academic intentions is not part of this study but may be an important influence in the student decision making process for determining their academic wants and needs. Further study using a qualitative approach could reveal very important information that relates to the apparent successes or failures of an academic program. The intent of students is an extremely important factor in determining course grades, attrition from programs, and involvement in academic programs. Intent is a strong determining factor in academic success of students that is often overlooked. Failure and attrition from a course is

often a carefully measured choice that is weighed carefully by students. In nontraditional students at community colleges, deciding to fail courses or withdraw from programs is often a moral and/or survival choice. These choices should not represent failure of an academic program or the failure of the student. The absence of soft data in this study and the hidden impact it has on the hard data could lead to misinterpretations about developmental mathematics program successes and failures. Continued research involving both quantitative and qualitative methods is needed for continued redesign improvements for developmental mathematics programs.

CHAPTER IV: RESEARCH FINDINGS

Open access to any student at community colleges creates a higher academic environment where many of the students are in need of developmental coursework to prepare them for college level coursework. For many community college students, mathematics is one of the academic disciplines in which students are underprepared for college level coursework and developmental education is necessary for fulfilling their desires in higher education (National Center for Education Statistics, 2012). Developmental programs are essential for promoting the American ideal of equal opportunity to all in higher education considering the open enrollment policies of community colleges (Brothen & Wambach, 2012). It is hoped that this research study will aid both faculty and administrators in community colleges in improving methods of academic support for students, the delivery of developmental courses, and methods to help students avoid developmental mathematics courses.

Course redesign in developmental mathematics has been a focus of many two-year community colleges in order to accelerate the process of getting students through the required sequence of courses. In the past, the developmental mathematics course sequences have followed the traditional structure of higher education courses with one course being offered in each semester (Ariovich & Walker, 2014). With community colleges being structured around two years of study, a developmental math sequence, which may be as many as three or four courses, may create a substantial time, financial, and motivational barrier to students less prepared for higher education (Ariovich & Walker, 2014; Bailey, Jeong, & Choo, 2010; Bonham & Boylan, 2012). As noted previously, approximately 60% of community college students start their college career in a developmental course with less than half of these students, or less than 30% of students entering college, completing or passing the initial developmental course

(Rutschow & Schneider, 2011). In addition, Bahr (2008) indicated that as many as 81% of students taking a developmental mathematics course do not obtain a degree. Similarly, research by the Community College Research Center (2014), showed that only about 28% of students who take a remedial course end up earning a degree within eight years (Community College Research Center, 2014). The need for redesign of developmental mathematics programs in community colleges is obvious.

Many community colleges have addressed this lack of success of traditional developmental mathematics programs by redesigning their programs to include methods that attempt to help students avoid taking developmental mathematics and accelerate movement through courses and sequences. A major component of many of these design modifications is the use of technology for delivery of the course content synchronously and asynchronously, enabling delivery of the course content both in-class and at a distance (Zientek, Skidmore, Saxon, & Edmonson, 2015).

This research study investigated the impact of a redesigned developmental mathematics program at Heartland Community College that is structured around a technology-enhanced, computer-based course delivery system that modularizes the coursework. Modularization of the course content enables students to complete coursework at their own pace, which theoretically allows for acceleration of the necessary developmental mathematics coursework (Ariovich & Walker, 2014). Although research in computer-assisted developmental mathematics has increased in recent years, comprehensive research in the effectiveness of computer-aided developmental mathematics area is still lacking (Rutschow & Schneider, 2011; Zavarella & Ignash, 2009; Zientek, Skidmore, Saxon, & Edmonson, 2015).

Heartland Community College also has a dual enrollment program that provides students the opportunity to take college-level courses, and courses to remediate academic deficiencies, while still in high school. Dual enrollment courses, regardless of academic discipline, have been reported to improve student overall achievement in college in comparison to students who have not had dual enrollment courses (Hoffman, Vargas, & Santos, 2009). The research by Hoffman et al., indicates that dual enrollment courses not only help students avoid college coursework once in college, but that dual enrollment courses also better prepare students for the rigors of higher education. As noted by Karp, Calcagno, Hughes, Jeong, and Bailey (2007), although dual enrollment courses are widely used, the effectiveness of these programs on student achievement in higher education is not well known.

Heartland Community College is located in a community college district in Illinois that serves a substantial rural population. The impact of technology on student academic success becomes a question due to a technological infrastructure in rural parts of the United States. Many students in rural areas suffer from a lack of modern technological infrastructure (Cejda, 2010). The lack of access to computer-based developmental mathematics from a rural location, for simply completing assignments or from the course being completely online, may have a negative impact on their student academic success that is unrelated to academic ability (Cejda, 2010; Leist & Travis, 2010).

Data obtained from the developmental mathematics programs at Heartland Community College from Fall 2008 through the Spring 2016 semesters, was analyzed in an attempt to determine if the acceleration of students in computer-based developmental mathematics, use of dual enrollment courses in high school, and the rural location of students impacts student academic success in developmental mathematics. Academic success, for purposes of this

research, was measured based on student final course grades, completing courses with a passing grade, and obtaining an associate's degree. The objective of this research study was to determine if student academic success in developmental math varies with students having taken dual enrollment courses, rural or non-rural location of indicated home address, course being computer-based or traditional, and course delivery being on campus or online. Gender, age, ethnicity, year in school, and ACT mathematics score were also analyzed to determine if these variables influence any of the variables of concern and whether they impact student academic success when taking developmental mathematics.

A combination of descriptive statistics, Pearson chi-square testing, and independent-samples *t*-tests were used to analyze the research questions. This chapter presents the results of the statistical tests related to those research questions. It is hoped that results of this research will help both faculty and administrators in community colleges make better informed decisions when attempting to implement optimal designs for supporting students needing developmental mathematics courses.

Research Questions

The three research questions addressed by this study were:

- RQ 1. Are students who have taken dual enrollment courses in high school more academically successful in computer-based developmental mathematics courses and programs than students who have not had dual enrollment courses?
- RQ 2. Are students who live in rural areas academically less successful in computer-based developmental mathematics than students who live in non-rural areas?

RQ 3. Does the curriculum and instruction delivery method used in developmental mathematics courses have a significant relationship with successful course completion, sequence completion, and completion of academic programs of study?

Research Variables

Table 4 below displays a summary of the independent and dependent variables analyzed in this study. Following Table 4, Table 5 displays a breakdown of percentages within variable categories and the total number of records associated with identifiers for those variables.

Table 4

Study Variables

Variables	Variable Categories	Variable Type & Level of Measurement
Dual enrollment	1 = Dual enrollment taken 2 = No dual enrollment taken	Independent Nominal
Student residency	1 = Non-rural 2 = Rural 3 = Undefined	Independent Nominal
Course delivery method	1 = Not online 2 = Online	Independent Nominal
Age	15 – 87 years	Independent Ordinal
Gender	1 = Male 2 = Female 3 = Undeclared	Independent Nominal
Ethnicity	1 = White 2 = Black 3 = Hispanic 4 = Other (Asian, American Indian/Pacific Islander, Non-resident Alien, Multi-ethnic)	Independent Nominal
Year developmental mathematics course taken	1 = 0 to 1 year 2 = 1 to 2 years 3 = 2 or more years	Independent Ordinal
ACT mathematics exam score	9 – 30	Independent Ordinal
Course grade	1 = Pass (A, B, C, Pass) 2 = No Pass (D, F, No Pass)	Dependent Nominal
Course completion	1 = Pass (A, B, C, Pass) 2 = No Pass (D, F, No Pass, Withdrawn)	Dependent Nominal
Degree attainment	1 = Degree (Associate in Arts, Associate in Applied Science, Associate in Engineering Science, Associate in Science) 2 = No Degree	Dependent Nominal

Table 5

Percentages and Total Records for Groups within the Sample

Variable	Percentage	Total Records
Dual enrollment		
Dual enrollment taken	5.9%	698
No dual enrollment taken	94.1%	11,108
Residency		
Rural	28.7%	3,390
Non-rural	71.3%	8,413
Course instructional method		
Traditional	39.5%	8,904
Computer-based	60.5%	13,642
Course delivery method within computer-based developmental mathematics courses		
On-campus	90.9%	10,729
Online	9.1%	1,079
Year in school course taken		
0 to 1 year	38.1%	4,279
1 to 2 years	31.3%	3,511
2 or more years	30.6%	3,438
Age		
19 years or younger	26.9%	3,018
20 to 25 years	47.7%	5,355
26 years or older	25.4%	2,855
Gender		
Male	45.6%	5,120
Female	54.3%	6,097
Ethnicity		
White	71.6%	8,035
Black	15.6%	1,748
Hispanic	5.5%	616
Other (Asian, American Indian or Pacific Islander, Non-resident Alien, Multi-ethnic)	7.4%	829
ACT mathematics exam scores		
No ACT mathematics exam score	85%	19,238
ACT mathematics exam score	15%	3,308

Results

Data associated with students who took math courses at Heartland Community College in Normal, Illinois, was obtained for 23 semesters, Fall 2008 through Spring 2016 semesters. The data were aggregated and variables were labeled to analyze the impact of dual enrollment courses in high school, the rural residency of students, and computer-based delivery on student academic success in developmental mathematics. For purposes of this research, data related to students in college-level mathematics were removed in order that only records of students in developmental mathematics were analyzed. The removal of college level mathematics records reduced the number of students from 40,689 to 22,546. The new aggregated data set containing only variable information related to developmental mathematics students was then used as the working data file for analyzing the research and control variables.

Preliminary Control Variable Analysis

Along with the analysis of the targeted research variables, additional independent variables were examined to determine what, if any, relationships existed with the dependent variables. The research questions were taken into consideration when conducting the preliminary analysis of the control variables. For example, if the research question was only concerned with computer-based developmental mathematics, the control variable was only analyzed using student records from only computer-based courses. The analysis was completed to obtain evidence on whether analysis of control variables was necessary in the evaluation of the research hypotheses. *T*-tests and Pearson chi-square analyses were completed on the independent control variables of student age, gender, ethnicity, year in school math developmental mathematics course taken, and ACT mathematics score with the dependent variables of course grade, course completion, and degree attainment.

Analysis of the Control Variable of Age

Age and course grades. Using the course grades data file, descriptive statistics were conducted on the variables age and course grade to check for any inconsistencies in data and to ensure all grade identifiers not needed had been removed. The student record data file for all developmental mathematics students between the Fall 2008 and Spring 2016 semesters contained 22,546 student records. After removing all traditionally instructed developmental mathematics student records from the data file, 13,642 computer-based developmental mathematics student records remained. Descriptive statistics indicated the data file contained one student record without an age recorded, so the student record was removed and reduced the data file size to 13,641. The variable identifiers associated with course grade that included the identifiers of incomplete, replaced grade, audit, withdrawn, making progress, and no grade recorded were manually removed from the data file prior to completing the *t*-testing. Removal of those identifiers reduced the number of student records being analyzed to 10,073, or 45% of the original number of records.

An independent samples *t*-test was conducted for student age (IV) in computer-based developmental mathematics and student grades base on pass or no pass (DV). There was no statistically significant differences between Group 1, pass, (M=23.71, SD=7.87) and Group 2, no pass (M=23.64, SD=7.47), $t_{(10072)} = .45, p = .651$. The *t*-value of .45 is not significant as the *p* value of .651 is $>.05$.

Age and course completion. Prior to conducting the independent samples *t*-test for age and course completion, all students identified as being withdrawn from a course were re-activated as a variable identifier for course grade (pass or no pass) so that an accurate evaluation of students not completing courses was completed. Including the withdrawn students in the

sample set brought the student record count back up to 11,806 records, or 53% of the original computer-based developmental mathematics student record set.

An independent samples t -test was conducted for computer-based developmental mathematics student age (IV) and course completion and non-course completion (DV). There was no significant difference between Group 1, course completers, ($M=23.63$, $SD=7.46$) and Group 2, course non-completers ($M=23.79$, $SD=7.72$), $t_{(11804)} = -1.1$, $p = .259$. The t -value of -1.1 is not significant as the p value of .259 is $>.05$.

Age and degree attainment. Prior to conducting the analysis of age and degree attainment, identical students were removed so a degree earned by a student was not counted more than once; this reduced the count to 6,653 student records, or 30% of the original student record set. Eliminating duplicate degrees and certificates ensured that associate degrees were only counted once.

An independent samples t -test was conducted for computer-based developmental mathematics student age (IV) and degree attainment (DV). There was no significant difference between Group 1, degree attained, ($M=23.76$, $SD=7.25$) and Group 2, no degree attained ($M=24.01$, $SD=7.53$), $t_{(6461)} = -.92$, $p = .36$. The t -value of -.92 is not significant as the p value of .36 is $>.05$.

Analysis of the Control Variable of Gender

Gender and course grades. Using the data file for course grades, the independent variable of gender was evaluated using Pearson chi-square analysis to test for independence of gender and course grade. The data file contained 16,425 of the original 22,546 developmental mathematics student records. Descriptive statistics were conducted for the variables gender and course grade was to identify any inconsistencies in data and to ensure all grade identifiers not

needed had been cleared. There were 10 instances where gender type was not indicated. The student records for the undeclared gender students were eliminated, reducing the student record count to 16,415, or 73% of the original developmental mathematics student data set.

A two-way contingency table analysis was then conducted on student gender (IV), with two levels (male and female), and course grades (DV), with two levels (pass and no pass), to investigate the level of association between the student gender and course grade. Student gender and course grades were found to be significantly related, Pearson $X^2_{(1)} = 137.1, p = .000$.

Although age is related to developmental mathematics student course grade, the phi coefficient of $-.091$ indicated that the association between the two variables is very weak.

Gender and course completion. The course completion data file that was created was used for the analysis of gender and course completion. The course completion data file contained 19,566, or 87% of the developmental mathematics data set of 22,546 student records. A descriptive analysis of gender and course completion revealed 12 undeclared student gender records. The 12 records were removed, reducing the number of student records to 19,554, or 87% of the original developmental mathematics data set.

A two-way contingency table analysis was conducted to determine the level of association between the variables of student gender and course completion (pass and no pass). Student gender and course completion were found to be significantly related, Pearson $X^2_{(1)} = 197.3, p = .000$. Although age is related to developmental mathematics student course completion, the phi coefficient of $-.1$ indicated that the association between the two variables is very weak.

Gender and degree attainment. An analysis of gender and degree attainment was conducted using the degree attainment data file that was created. The degree attainment file contained 10,985 student records, or 49% of the original developmental mathematics data set due to the elimination of duplicate students in the records. Certificates and repeated individual degrees associated to individual students were eliminated. Student records used in this study were based on the semester the course was taken so if a student had earned a degree or certificate, that degree or certificate record was recorded for each individual course record for that student. If a student earned one Associate of Arts degree and took three developmental mathematics courses, the one degree was listed for each record because the degree is associated to that student. In order to get an accurate count of degrees earned, repeats were eliminated from the student records being analyzed. Certificate earners were eliminated from the records analyzed because not all certificate types require completion of developmental mathematics, and therefore, the relationship between developmental mathematics and certificate attainment did not always exist. Elimination of repeated degrees and certificates allowed for an accurate analysis of degree and no degree variable identifiers in the Pearson chi-square analysis. Prior to the analysis of gender, a descriptive analysis of the data set revealed 11 undeclared student gender records. The removal of the undeclared student gender records reduced the record count to 10,974, or 49% of the original developmental mathematics data set.

A two-way contingency table analysis was conducted to determine the level of association between gender and degree attainment (degree and no degree). Student gender and degree attainment were found to be significantly related, Pearson $X^2_{(1)} = 49.7, p = .000$. Although the gender of developmental mathematics students is related to degree attainment, the phi coefficient of $-.067$ indicated the association between the two variables is very weak.

Analysis of the Control Variable of Ethnicity

Ethnicity and course grades. Using the data file for course grades, the independent variable of ethnicity was evaluated using Pearson chi-square analysis to test for independence of ethnicity and course grade. The data file contained 16,425 of the original 22,546 developmental mathematics student records. Descriptive statistics of the variables for ethnicity and course grade were evaluated for any inconsistencies and to ensure all grade identifiers not needed had been cleared. Frequencies revealed that 353 records where students had declared no ethnicity. The student records with no ethnicity declared were eliminated from the data file, reducing the student record count to 16,072, or 71% of the original developmental mathematics student data sample.

A two-way contingency table analysis was then conducted on student ethnicity, with three levels (white, black, and other), and course grade (pass and no pass). Student ethnicity and course grade were found to be significantly related, Pearson $X^2_{(2)} = 423.5, p = .000$. Although ethnicity is related to developmental mathematics student course grade, Cramer's V of .162 indicated that the association between the two variables is weak.

Ethnicity and course completion. The course completion data file that was created was used for the analysis of ethnicity and course completion. The course completion data file contained 19,566, or 87% of the developmental mathematics data set of 22,546 records. A descriptive analysis of ethnicity and course completion revealed 425 undeclared student ethnicity records. The 425 student records were removed, reducing the number of student records to 19,141, or 85% of the of the original developmental mathematics student data set.

A two-way contingency table analysis was conducted to determine the level of association between the variables of student ethnicity (white, black, and other) and course

completion (pass and no pass). Student ethnicity and course completion were found to be significantly related, Pearson $X^2_{(2)} = 578.6$, $p = .000$. Although ethnicity is related to developmental mathematics student course completion, Cramer's V of .174 indicated that the association between the two variables is weak.

Ethnicity and degree attainment. Analysis of ethnicity and degree attainment was completed using the degree attainment data file that was created. The degree attainment file contained 10,985 student records, or 49% of the original developmental mathematics student data set. Descriptive statistics were analyzed for inconsistencies in the student data and to ensure that duplicate student degrees and certificates were eliminated from the student data set. Descriptive analysis revealed 254 students with no declared ethnicity. The removal of the student records with undeclared ethnicity reduced the student record count to 10,731, or 48% of the original developmental mathematics student data set.

A two-way contingency table analysis was conducted to determine the level of association between the variables of ethnicity (white, black, and other) and degree attainment (degree and no degree/cert). Student ethnicity and degree attainment were found to be significantly related, Pearson $X^2_{(2)} = 182.9$, $p = .000$. Although developmental mathematics student gender is related to degree attainment, Cramer's V of .131 indicated that the association between the two variables is very weak.

Analysis of the Control Variable of Year in School

Year in school and course grades. Using the data file for course grades, the independent variable of year in school was evaluated using Pearson chi-square analysis to test for the level of association between year in school and course grade. The data file contained 16,425 of the original 22,546 developmental mathematics student records. Descriptive statistics of the

variables year in school and course grade was used to evaluate for any inconsistencies in data and to ensure all grade identifiers not needed had been eliminated from the data set.

A two-way contingency table analysis was conducted on year in school mathematics course taken, with three levels (under 1 year, 1 to 2 years, and 2 or more years), and course grade (pass and no pass). Year in school and course grades were found to not be significantly related, Pearson $X^2_{(2)} = 3.2$, $p = .200$.

Year in school and course completion. The course completion data file was used for the analysis of year in school first developmental mathematics course was taken and course completion. The course completion data file contained 19,566, or 87%, of the original developmental mathematics data set of 22,546 student records. A descriptive analysis of year in school and course completion revealed no inconsistencies or missing data in the variable set.

A two-way contingency table analysis was conducted to determine the level of association between year in school first developmental mathematics course taken (under 1 year, 1 to 2 years, and 2 or more years) and course completion (pass and no pass). Student year in school and course completion were found to be significantly related, Pearson $X^2_{(2)} = 10.8$, $p = .005$. Although year in school is related to course completion in developmental mathematics, Cramer's V of .023 indicated that the association between the two variables is very weak.

Year in school and degree attainment. Analysis of year in school and degree attainment was completed using the degree attainment data file that was created for control variable analysis. The degree attainment file contained 10,985 student records, or 49% of the original developmental mathematics student data set. Descriptive analysis of year in school and degree attainment revealed no inconsistencies or missing data in the variable set.

A two-way contingency table analysis was conducted to determine the level of association between the variables of year in school developmental mathematics taken (under 1 year, 1 to 2 years, and 2 or more years) and degree attainment (degree and no degree/cert). Student year in school for first developmental mathematics course and degree attainment were found to be significantly related, Pearson $X^2_{(2)} = 234.8$, $p = .000$. Although the year first developmental mathematics courses are taken is associated to degree attainment, Cramer's V of .146 indicated that the association between the two variables is very weak.

Analysis of the Control Variable ACT Mathematics Exam Score

ACT mathematics exam score and course grades. Using the course grades data file, descriptive statistics were conducted on the variables age and course grade to check for any inconsistencies in data and to make sure all grade identifiers not needed had been removed. The student record data file for all developmental mathematics students between the Fall 2008 and Spring 2016 semesters contained 22,546 student records. After removing all traditionally instructed developmental mathematics student records from the data file, 13,642 computer-based developmental mathematics student records remained. Descriptive statistics indicated the data file contained one student record without an age recorded, so the student record was removed and reduced the data file size to 13,641. The variable identifiers associated with course grade that included the identifiers of incomplete, replaced grade, audit, withdrawn, making progress, and no grade recorded were manually removed from the data file prior to completing the *t*-testing. In addition, student records containing no record of ACT mathematics exam score were analyzed. Removal of those identifiers reduced the number of student records being analyzed to 3,308, or 15% of the original number of records.

The independent variable of ACT mathematics exam score was evaluated with the dependent variable, course grades, using an independent samples *t*-test. An independent samples *t*-test was conducted for students in computer-based developmental mathematics with a recorded ACT mathematics score (IV) based on not passing and passing (DV). There was a significant difference between Group 1, no pass, (M=16.79, SD=2.3) and Group 2, pass (M=17.92, SD=2.5), $t_{(3306)} = -13.01$, $p = .000$. The *t*-value of -13.01 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = -.47$) suggested a moderate practical significance.

ACT mathematics exam score and course completion. Prior to conducting the independent samples *t*-test for ACT mathematics exam score and course completion, variable identifiers associated to the coarse grade identifier of withdrawal were activated in the data file. Activating these identifiers brought the record count back up to 4,280 records, or 19% of the original computer-based developmental mathematics student record set.

An independent samples *t*-test was conducted for computer-based developmental mathematics student ACT mathematics exam scores (IV) for course completion and non-course completion (DV). There was a significant difference between Group 1, course completers, (M=17.92, SD=2.5) and Group 2, course non-completers (M=16.87, SD=2.4), $t_{(3705)} = 13.05$, $p = .000$. The *t*-value of 13.05 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = .43$) suggested a small to moderate practical significance.

ACT Mathematics exam score and degree attainment. For analysis of degree attainment with ACT mathematics exam score, the elimination of duplicate students and certificates from the data set resulted in the reduction in the student record count to 1,997 student records, or 9% or the original computer-based developmental mathematics student record sample.

An independent samples *t*-test was conducted for computer-based developmental mathematics student ACT mathematics exam scores (IV) and degree earned (DV). There was a significant difference between Group 1, degree earned, (M=18.41, SD=2.65) and Group 2, no degree earned (M=17.31, SD=2.55), $t_{(1952)} = 6.8, p = .000$. The *t*-value of 6.8 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = .42$) suggested a small to moderate practical significance.

Analysis of Research Questions

Research Question 1

The first research question poses: Are students who have taken dual enrollment courses in high school more academically successful in a computer-based developmental mathematics courses and programs than students who have not had dual enrollment courses?

A series of three Pearson chi-square tests were conducted using the independent variable of dual enrollment and the dependent variables: course grade, course completion, and degree attainment. The nonparametric chi-square test was chosen to analyze the variables of interest in order to determine if the distribution of frequencies in dependent variables are what would be expected to occur by chance, suggesting the independent variable does not influence the dependent variable, or whether the distribution of frequencies in dependent variables appear to be being influenced by the independent variable (Salkind, 2014). Hypotheses for each analysis was created to address course grade, course completion, and degree attainment labeled as hypothesis a, b, and c, respectively.

Analysis of hypotheses 1a.

Null Hypothesis 1a

H₀ – There is no difference in overall course grades for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Research Hypothesis 1a

H_a – There is a difference in overall course grades for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

The working data set was reduced from 22,546 to 13,642 students by removing all traditional developmental mathematics course data, leaving only students who completed computer-based developmental mathematics courses in the analysis. All grades identified as “withdrawals” were removed from the data set, along with two grades of “F” and three grades listed as “incompletes.” The “F” grades were removed from the data set because computer-based mathematics courses are only graded as pass or no pass and incomplete grades are not possible in the computer-based modular system. Removal of withdrawals and non-appropriate grade records reduced the study sample to 10,020, or 44% of the original data set, for all developmental mathematics during the research time period.

Descriptive statistics of the data were conducted to investigate for any missing data or inconsistencies prior to completing the Pearson chi-square analysis of dual enrollment and course grade. A two-way contingency table analysis was conducted on dual enrollment (IV), with two levels (dual enrollment taken and no dual enrollment taken), and course grades (DV), (pass and no pass), to examine the association between the independent and dependent variables. Dual

enrollment and course grade were found to not be significantly related, Pearson $X^2_{(1)} = .48$, $p = .49$, therefore the null hypothesis is accepted. Results of the Pearson chi-square test indicate that there was no association between students taking dual enrollment courses and final course grades in developmental mathematics courses.

Analysis of hypothesis 1b.

Null Hypothesis 1b

H_0 – There is no difference in course completion rates for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Research Hypothesis 1b

H_a – There is a difference in course completion rates for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

To evaluate the association between dual enrollment and course completion, the independent variable of dual enrollment and dependent variable of pass/no pass were analyzed using Pearson's chi-square analysis. Beginning with a sample of 22,546, students enrolled in traditional developmental mathematics courses and those receiving non-appropriate grade records were removed from the data set, leaving a sample of 11,806, 52% of the original developmental mathematics data set for analysis.

Descriptive statistics were conducted to investigate for any missing or inconsistencies prior to completing the Pearson chi-square analysis of dual enrollment and course completion. A two-way contingency table analysis was conducted on dual enrollment (dual enrollment taken and no dual enrollment taken) and course completion (pass, no pass) of students taking

developmental mathematics courses to test for independence between the independent and dependent variable. Dual enrollment and course completion were found to be significantly related, Pearson $X^2_{(1)} = .02, p = .023$, therefore the null hypothesis is rejected in reference to course completion. Although the analysis of course completion showed an association between developmental mathematics students who had taken a dual enrollment course and course completion, the phi coefficient of .021 indicated that the association between the two variables is weak.

Control variable analysis with dual enrollment and course completion was completed using elaboration of Pearson chi-square testing. A series of three-way contingency table analyses with controls were conducted to analyze the effect of the control variables of gender, ethnicity, and year in school. To evaluate the relationship of ACT mathematics exam scores with dual enrollment and course completion, independent samples *t*-tests were used to evaluate the relationship of ACT mathematics exam score with dual enrollment and course completion. A binary logistic regression was used to investigate if a significant relationship between ACT scores and course completion exists.

When controlling for gender, there was a significant relationship between dual enrollment and course completion for males, while controlling for females, the relationship between dual enrollment and course completion no longer exists. When controlling for ethnicity, there was a significant relationship between dual enrollment courses and course completion when controlling for black students. When controlling for year in school, students in their first year of college are indicated to have a significance in the relationship of dual enrollment and course completion. The two-way contingency analysis with controls for dual enrollment and course completion

indicated that a partial significant relationship for students who are male, black students, and first year students, for other controls, the relationship is no longer significant.

An independent samples *t*-test was conducted to evaluate ACT mathematics exam scores (IV) for computer-based developmental mathematics students who complete courses and those who do not complete courses (DV). There was a significant difference between Group 1, course completers, (M=18.03, SD=2.62) and Group 2, non-course completers (M=16.88, SD=2.42), $t_{(4226)} = 14.71$, $p = .000$. The *t*-value of 14.71 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = .46$) suggested a moderate practical significance.

An independent samples *t*-test was also conducted to evaluate ACT mathematics exam scores (IV) for computer-based developmental mathematics students who had taken dual enrollment and not taken dual enrollment (DV). There was a significant difference between Group 1, dual enrollment, (M=17.94, SD=2.48) and Group 2, no dual enrollment (M=17.39, SD=2.60), $t_{(4867)} = 4.50$, $p = .000$. The *t*-value of 4.50 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = 0.22$) suggested a small practical significance.

A binary logistic regression analysis was also conducted on ACT mathematics scores (IV) and course completion for computer-based developmental mathematics (DV) in order to determine if a relationship between the variables existed. The logistic regression indicated that for an increase of one interval score on the ACT mathematics test, the odds of completing a computer-based developmental mathematics course decreased by a factor of 0.835.

Analysis of hypothesis 1c.

Null Hypothesis 1c

H_0 – There is no difference in degree attainment for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

Research Hypothesis 1c

H_a – There is a difference in degree attainment for computer-based developmental mathematics students who take a dual enrollment courses and those who do not take dual enrollment courses.

To evaluate the association between dual enrollment and degree attainment, the original working data file were analyzed for duplicate student records based on degree type. After identifying the duplicate records based on degree type, 11,317 duplicate records were identified and removed from the original data file of 22,546 student records, leaving a sample of 11,229 (49.8%) student records.

A new variable for degree attainment was created by aggregating the four degree types of (a) Associate in Arts, (b) Associate in Engineering Science, (c) Associate in Applied Science, and (d) Associate in Science into a new category labeled as “degree,” in addition to identifiers for “certification” and “no degree/certification.” All students who earned certifications were removed from the data file because not all certification earners are required to complete developmental mathematics. In addition, all developmental mathematics students in traditional courses were removed from the data file. Removing certification earners and traditional course takers from the data file further reduced the data file size to 6,492 (29%) student records.

Descriptive statistics were conducted for dual enrollment and degree attainment to ensure that no data were missing and no inconsistencies in the records existed. A two-way contingency table analysis was then conducted to determine the level of association between dual enrollment courses (dual enrollment and no dual enrollment) and degree attainment of students who have taken developmental mathematics courses (degree and no degree/certification). Dual enrollment and degree attainment were found to be significantly associated, Pearson $X^2_{(1)} = 14.03$, $p = .000$, therefore the null hypothesis is rejected in reference to degree attainment. Although the degree attainment is associated with dual enrollment course takers who have taken developmental mathematics, the phi coefficient of 0.046 indicated that the association between the two variables is very weak.

Control variable analysis with dual enrollment and degree attainment was completed using elaboration of Pearson chi-square testing using two-way contingency table analysis with controls. A series of two-way contingency table analyses with controls were conducted to analyze the effect of the control variables of gender, ethnicity, and year in school. To evaluate the relationship of ACT mathematics exam scores with dual enrollment and degree attainment, independent samples t -tests were used to evaluate the relationship of ACT mathematics exam score with dual enrollment and degree attainment. A binary logistic regression was used to investigate if a significant relationship between ACT scores and course completion exists.

When controlling for gender, there is a significant relationship between dual enrollment and degree attainment for both males and females. When controlling for ethnicity, there is a significant relationship between dual enrollment courses and degree attainment for white students. When controlling for year in school, students in their first year of college are indicated to have a significance in the relationship of dual enrollment and degree attainment. The results

of the Pearson chi-square control variable analysis indicate that white, males and females in their first year of school were the significant groups.

An independent samples *t*-test was conducted to evaluate the mean ACT mathematics exam scores (IV) for computer-based developmental mathematics students who had taken dual enrollment and not taken dual enrollment (DV). There was a significant difference between Group 1, dual enrollment, (M=17.94, SD=2.48) and Group 2, no dual enrollment (M=17.39, SD=2.60), $t_{(4867)} = 4.50, p = .000$. The *t*-value of 4.50 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = 0.22$) suggested a small practical significance.

An independent samples *t*-test was conducted to evaluate the mean ACT mathematics exam scores (IV) for computer-based developmental mathematics students who earned a degree and not earned a degree (DV). There was a significant difference between Group 1, degree earners, (M=18.26, SD=2.63) and Group 2, non-degree earners (M=17.23, SD=2.52), $t_{(4759)} = 11.27, p = .000$. The *t*-value of 11.27 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = 0.40$) suggested a small to moderate practical significance.

A binary logistic regression was also completed on data for ACT mathematics scores and degree attainment for students who have taken computer-based to determine if a relationship between the variables existed. The logistic regression indicated that there was a statistically significant difference between ACT mathematics scores and degree attainment. The logistic regression indicated that for an increase of one interval score on the ACT mathematics test, the odds of developmental mathematics students obtaining a degree decreased by a factor of 0.863.

Research Question 2

The second research question poses: Are students who live in rural areas academically less successful in computer based developmental mathematics than students who live in non-rural areas?

Analysis of hypothesis 2a.

Null Hypothesis 2a

H_0 – Course completion rates for students who reside in rural areas will not differ for computer-based developmental mathematics students in comparison to those who reside in non-rural locations.

Research Hypothesis 2a

H_a – Course completion rates for students who reside in rural areas will differ for computer-based developmental mathematics students in comparison to those who reside in non-rural locations.

Descriptive statistics and two Pearson chi-square tests were conducted on the independent variable of student residency and the dependent variables of course completion and degree attainment to determine if the variables were independent of each other.

The data file that contained all student records from Heartland Community College's developmental mathematics courses from the Fall 2008 semester to Spring 2016 semesters was used for the analysis of student residency and course completion. For the analysis of student residency and course completion, the first step was to remove student records that contained no address information. Twenty records with no addresses were found and eliminated from the data file, reducing the number of students to 22,526. The next step was to remove all recorded grade data that was not essential for grade analysis. This processes included the removal of grade data

identified as incomplete, replaced grade, audit, making progress, or no grade recorded from the sample set, reducing the number of students to 19,563. The final process was the removal of all developmental mathematics student records from courses in the traditional mathematics instructional format, which were all student records prior to the Fall 2011 semester. Removal of all traditional instructional developmental mathematics student records reduced the number of total students to 11,803, or 52% of the original data set.

Descriptive statistics were analyzed for student residency and course completion to confirm no data were missing and no inconsistencies in the student records existed. A two-way contingency table analysis was conducted to determine if student residency (rural and non-rural) influenced course completion of students who had taken computer-based developmental mathematics courses (pass and no pass). Student residency and course completion were found to be significantly associated, Pearson $X^2_{(1)} = 42.5$, $p = .000$, therefore the null hypothesis is rejected. Although student residency is associated with course completion in computer-based developmental mathematics, the phi coefficient of -0.060 indicated that the association between the two variables is very weak.

Control variable analysis with student residency and course completion was completed using elaboration of Pearson chi-square testing using two-way contingency table analysis with controls. A series of two-way contingency table analyses with controls were conducted to analyze the effect of the control variables of gender, ethnicity, and year in school. To evaluate the relationship of ACT mathematics exam scores with student residency and course completion, independent samples t -tests were used to evaluate the relationship of ACT mathematics exam score with student residency and course completion. A binary logistic regression was used to investigate if a significant relationship between ACT scores and course completion exists.

When controlling for gender, there was no significant relationship between student residency and course completion. When controlling for ethnicity, there was a significant weak relationship between student residency and course completion for white students. When controlling for year in school, a weak significance in the relationship the year students take the course and student residency with course completion was indicated.

An independent samples *t*-test was conducted to evaluate ACT mathematics exam scores (IV) for computer-based developmental mathematics students who complete courses and those who do not complete courses (DV). There was a significant difference between Group 1, course completers (M=18.03, SD=2.62) and Group 2, course non-completers (M=16.88, SD=2.42), $t_{(4226)} = 14.71, p = .000$. The *t*-value of 14.71 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = 0.46$) suggested a moderate practical significance.

An independent samples *t*-test was conducted to evaluate the mean ACT mathematics exam scores (IV) for computer-based developmental mathematics students who had non-rural residency and rural residency (DV). There was a significant difference between Group 1, non-rural residency, (M=17.35, SD=2.59) and Group 2, rural residency (M=17.65, SD=2.58), $t_{(4855)} = -3.95, p = .000$. The *t*-value of 3.95 is significant as the *p* value of .000 is <.05. Cohen's effect size value ($d = -0.12$) suggested a small practical significance.

A binary logistic regression was also conducted on ACT mathematics scores and course completion for computer-based developmental mathematics in order to determine if a relationship between the variables existed. The logistic regression indicated that with an increase in of one interval score on the ACT mathematics test the odds of completing a computer-based developmental mathematics course decreased by a factor of 0.835.

Analysis of hypothesis 2b.

Null Hypothesis 2b

H₀ – Degree attainment rates for students who reside in rural areas, and who take at least one computer-based developmental course online, will not differ from students who do not reside in rural areas, and who take at least one computer-based developmental math course online.

Research Hypothesis 2b

H_a – Degree attainment rates for students who reside in rural areas, who take at least one computer-based developmental course online, will differ from students who do not reside in rural areas who take at least one computer-based developmental math course online.

As part of the evaluation of student residency and computer-based developmental mathematics, a second hypotheses associated with research question 2, identified as null and research hypotheses 2b, was developed. The null hypothesis 2b and research hypothesis 2b were specifically development to determine if online courses and student residency influenced degree attainment in computer-based developmental mathematics.

Descriptive statistics and a Pearson chi-square test was conducted on the independent variable of student residency and the dependent variable of course degree attainment to find if taking developmental mathematics courses online influenced degree attainment. Online courses were specifically analyzed to find if a reduced level of technological access appears to exist and is reflected in student degree attainment rates for those students residing in rural areas.

Using the working data file that contained all student records for the developmental mathematics program from Fall 2008 to Spring 2016 semesters, all student records for students who had taken developmental mathematics prior to the program moving to a computer-based

format, students not taking any developmental mathematics classes online, and students receiving certificates, were eliminated from the prior to analysis. Eliminating these student records from the data file reduced the number of student records to 1,156 from 22,546. The final step prior to analysis was the elimination of all duplicate students where multiple degree earned records were recorded. Repeated degree records were removed so one degree earned was not analyzed more than once. This reduced the number of student records to 850, or 3.7%, of the original data file.

Descriptive statistics of the data were conducted for student residency, degree attainment, and course delivery method to ensure that no data were missing and no inconsistencies existed, and that only online developmental mathematics courses were being included in the Pearson chi-square analysis. A two-way contingency table analysis was then conducted to determine the association between student residency (rural and non-rural) and degree attainment (degree and no degree or certification) for computer-based developmental mathematics courses delivered in the online course format. Student residency and degree attainment for students taking at least one online course were found to be not significantly associated, Pearson $X^2_{(1)} = .4$, $p = .523$, therefore the null hypothesis is accepted. Degree attainment rates for rural students taking at least one computer-based developmental mathematics course online do not differ significantly from students taking at least one developmental mathematics course online.

As a follow-up to the analysis of rural residency and degree attainment with online courses, degree attainment was also analyzed, but in this analysis, developmental mathematics courses taken online and on campus were both included in the analysis. Student residency and degree attainment for computer-based developmental mathematics students were found to not be significantly related, Pearson $X^2_{(1)} = 3.6$, $p = .059$, therefore the null hypothesis is accepted.

Degree attainment rates are not associated with student residency for students in computer-based developmental mathematics courses.

Research Question 3

The third research question poses: Does the curriculum and instruction delivery method used in developmental mathematics have a significant relationship with successful course completion and degree attainment?

A series of three descriptive statistics tests and Pearson chi-square tests were conducted on the independent variable of instructional method and dependent variables of course completion and degree attainment to determine if there was a relationship between the variables.

Analysis of hypothesis 3a.

Null Hypothesis 3a

H₀ – Course completion rate for students in computer-based developmental mathematics courses do not differ from students in traditional developmental mathematics courses.

Research Hypothesis 3a

H_a – Course completion rate for students in computer-based developmental mathematics courses do not differ from students in traditional developmental mathematics courses.

Using the original working data file, with the variable of pass/no-pass that was discussed earlier added to the data, the independent variable of instructional method and dependent variable of course completion were analyzed. Elimination of the course grades types which were irrelevant from the pass/no-pass variable, which represented the grades (a) incomplete, (b) replaced grade, (c) audit, (d) making progress, and (e) no recorded course grade, reduced the student record count from 22,546 to 19,566, or 87% of original data set.

Descriptive statistics were analyzed for course instructional method and course completion to ensure that no data were missing and no inconsistencies in the student records existed. After reviewing the descriptive analysis, a two-way contingency table analysis was conducted to determine the level of association between course instructional method (traditional graded dev math course and computer based p/np dev math course) and course completion (pass and no pass) in developmental mathematics courses. Course instructional method and course completion were found to be significantly associated, Pearson $X^2_{(1)} = 86.8$, $p = .000$, therefore the null hypothesis is rejected. Although the course instructional method is associated with course completion in developmental mathematics, the phi coefficient of -0.067 indicated that the association between the two variables is very weak.

Control variable analysis with traditional and computer-based course completion was completed using elaboration of Pearson chi-square testing using two-way contingency table analysis with controls. A series of two-way contingency table analyses with controls were conducted to analyze the effect of the control variables of gender, ethnicity, and year in school. To evaluate the relationship of ACT mathematics exam scores with course instructional method and course completion, independent samples t -tests were used to evaluate the relationship of ACT mathematics exam score with course instructional method and course completion. A binary logistic regression was used to investigate if a significant relationship between ACT scores and course instructional method exists.

When controlling for gender, there was a weak significant relationship between traditional and computer-based developmental mathematics course completion. When controlling for ethnicity, there is no significant relationship between traditional and computer-based courses for black students. All other ethnic groups indicated a weak significant

relationship between traditional and computer-based developmental mathematics courses. When controlling for year in school, a weak significant relationship for students in all years in school for the sample is indicated for traditional and computer-based developmental mathematics courses.

An independent samples *t*-test was conducted to evaluate the mean ACT mathematics exam scores (IV) for developmental mathematics students who had taken traditional developmental mathematics and computer-based mathematics (DV). There was a significant difference between Group 1, traditional developmental mathematics, ($M=17.96$, $SD=3.14$) and Group 2, computer-based developmental mathematics ($M=17.38$, $SD=2.45$), $t_{(4867)} = 5.1$, $p = .000$. The *t*-value of 5.1 is significant as the *p* value of .000 is $<.05$. Cohen's effect size value ($d = .021$) suggested a small practical significance.

An independent samples *t*-test was conducted to evaluate the mean ACT mathematics exam scores (IV) for developmental mathematics student course completion and non-course completion (DV). There was a significant difference between Group 1, course completers, ($M=18.03$, $SD=2.6$) and Group 2, course non-completers ($M=16.88$, $SD=2.4$), $t_{(4226)} = 14.7$, $p = .000$. The *t*-value of 14.7 is significant as the *p* value of .000 is $<.05$. Cohen's effect size value ($d = .46$) suggested a moderate practical significance.

A binary logistic regression was also completed on ACT mathematics scores and degree attainment for students in both traditional and computer-based developmental mathematics to determine if a relationship between the variables existed. The logistic regression indicated that with an increase in one interval score on the ACT mathematics test the odds of obtaining a degree for students who take computer-based developmental mathematics decreased by a factor of 0.863.

Analysis of hypothesis 3b.

Null Hypothesis 3b

H₀ – Degree attainment rates for students in computer-based developmental mathematics courses do not differ from students in traditional developmental mathematics courses.

Research Hypothesis 3b

H_a – Degree attainment rates for students in computer-based developmental mathematics courses do differ from students in traditional developmental mathematics courses.

The original working data file was used as the data file for analysis of null hypothesis 3b. The first step in the analysis of the null hypothesis 3b was to identify and eliminate duplicate student records so degree attainment was not counted more than one time. Cleaning the data of duplicate students reduced the number of student records from 22,546 to 11,229, or 49.8% of the original data set. Next, all certifications were eliminated from the data file because several certification programs at the college do not require taking or completing developmental mathematics courses, therefore, completing developmental mathematics may or may not be associated to obtaining a certification. Removing the certifications reduced the number of student records further to 10,870, or 48% of the original data set.

Descriptive statistics were conducted for course instructional method and degree attainment to ensure that no data was missing and no inconsistencies in the records existed. After reviewing the descriptive statistics, a two-way contingency table analysis was conducted to determine the level of association between course instructional method (traditional graded dev math course and computer based p/np dev math course) and degree attainment (degree and no degree or certification) in developmental mathematics courses. Course instructional method and degree attainment were found to be significantly associated, Pearson $X^2_{(1)} = 177.3, p = .000,$

therefore the null hypothesis is rejected. Although the course instructional method is associated with degree attainment for students in developmental mathematics, the phi coefficient of .128 indicated that the association between the two variables is weak.

Control variable analysis with traditional and computer-based degree attainment was completed through elaboration of Pearson chi-square testing using two-way contingency table analysis with controls. A series of two-way contingency table analyses with controls were conducted to analyze the effect of the control variables of gender, ethnicity, and year in school. To evaluate the relationship of ACT mathematics exam scores with course instructional method and degree attainment, independent samples *t*-tests were used to evaluate the relationship of ACT mathematics exam score with course instructional method and degree attainment. A binary logistic regression was used to investigate if a significant relationship between ACT mathematics exam scores and course instructional method exists.

When controlling for gender, there was a weak significant relationship between traditional and computer-based developmental mathematics degree attainment for both males and females. When controlling for ethnicity, there was a weak significant relationship between traditional and computer-based courses for all ethnicities. When controlling for the year in school the developmental mathematics course was taken, a weak significant relationship for students in both traditional and computer-based developmental mathematics and degree attainment was indicated.

An independent samples *t*-test was conducted to evaluate ACT mathematics exam scores (IV) for developmental mathematics students who had taken traditional developmental mathematics and computer-based mathematics (DV). There was a significant difference between Group 1, traditional developmental mathematics, ($M=17.96$, $SD=3.14$) and Group 2, computer-

based developmental mathematics ($M=17.38$, $SD=2.45$), $t_{(4867)} = 5.1$, $p = .000$. The t -value of 5.1 is significant as the p value of .000 is $<.05$. Cohen's effect size value ($d = .021$) suggested a small practical significance.

An independent samples t -test was conducted to evaluate the mean ACT mathematics exam scores (IV) for developmental mathematics students who those who earned degrees and not earned degrees (DV). There was a significant difference between Group 1, degree earners, ($M=18.69$, $SD=2.78$) and Group 2, non-degree earners ($M=17.41$, $SD=2.64$), $t_{(2228)} = 8.66$, $p = .000$. The t -value of 8.66 is significant as the p value of .000 is $<.05$. Cohen's effect size value ($d = .47$) suggested a moderate practical significance.

A binary logistic regression was also completed on ACT Mathematics scores and degree attainment in order to determine if a relationship between the variables existed. The logistic regression indicated that there was a significance between ACT mathematics score and degree attainment. The binary logistic regression also indicated that the odds of obtaining a degree increases with ACT mathematics score. For each one interval score increase on the ACT Mathematics test the odds of obtaining a degree for students who take computer-based developmental mathematics decreases by a factor of 0.863.

Analysis of hypothesis 3c.

Null Hypothesis 3c

H_0 – Course completion rates for students in online computer-based developmental mathematics courses do not differ from students in on-campus computer-based developmental mathematics courses.

Research Hypothesis 3c

H_a – Course completion rates for students in online computer-based developmental mathematics courses do differ from students in on-campus computer-based developmental mathematics courses.

The original working data file was used as the data file for analysis of null hypothesis 3c. The data file was aggregated by clearing the data set of all traditional, non-computer-based developmental math courses using the identifiers associated with the course instructional method variable. Removing all traditional developmental mathematics courses prior to Fall 2011 semester eliminated 8,904 student records of the original 22,546, leaving 13,642, or 61% of the student records. Next the course grade variable was used to eliminate the course grade variable identifiers that were not applicable for the analysis of hypotheses 3c. This process consolidated the data file to only include the pass/no pass identifiers for course grades and developmental mathematics courses that were associated with computer-based instructional courses. Consolidating the data file to only those variable identifiers reduced the total student record count to 11,808, or 52% of the original data file.

Descriptive statistics were then conducted for course delivery method and course completion to ensure that no data were missing and no inconsistencies in the records existed. After reviewing the descriptive analysis, a two-way contingency table analysis was conducted to determine the level of association between course delivery method (not online and online) and course completion (pass and no pass) for computer-based developmental mathematics courses. Course delivery method and course completion in computer-based developmental mathematics courses were found to be significantly associated, Pearson $X^2_{(1)} = 22.0$, $p = .000$, therefore the null hypothesis is rejected. Although the course instructional method is associated with degree

attainment for students in developmental mathematics, the phi coefficient of .043 indicated the association between the two variables was very weak.

Control variable analysis with online and face-to-face computer-based course completion was completed using elaboration of Pearson chi-square testing using two-way contingency table analysis with controls. A series of two-way contingency table analyses with controls were conducted to analyze the effect of the control variables of gender, ethnicity, and year in school. To evaluate the relationship of ACT mathematics exam scores with course delivery method and course completion, independent samples *t*-tests were used to evaluate the relationship of ACT mathematics exam score with course delivery method and course completion. A binary logistic regression was used to investigate if a significant relationship between ACT mathematics exam scores and course delivery method exists.

When controlling for gender, there was a weak significant relationship between online course completion and face-to-face course completion in computer-based developmental mathematics for females. When controlling for ethnicity, there was a weak significant relationship between online course completion and face-to-face course completion in computer-based developmental mathematics for all ethnicities. For Black students, the relationship between online and face-to-face was negative, while for White students and other ethnicities it was a positive relationship. When controlling for year in school, a weak significant relationship for students beyond their first year in school when taking a developmental mathematics course indicated a relationship between online course completion and face-to-face course completion in computer-based developmental mathematics.

An independent samples *t*-test was conducted to evaluate the mean ACT mathematics exam scores (IV) for computer-based developmental mathematics students who complete

courses and those who do not complete courses (DV). There was a significant difference between Group 1, course completers, ($M=18.03$, $SD=2.62$) and Group 2, course non-completers ($M=16.88$, $SD=2.42$), $t_{(4226)} = 14.71$, $p = .000$. The t -value of 14.71 is significant as the p value of .000 is $<.05$. Cohen's effect size value ($d = 0.46$) suggested a moderate practical significance.

An independent samples t -test was conducted to evaluate the mean ACT mathematics exam scores (IV) for computer-based developmental mathematics students who had taken courses face-to-face and online (DV). There was a significant difference between Group 1, face-to-face, ($M=17.43$, $SD=2.59$) and Group 2, online ($M=17.82$, $SD=2.58$), $t_{(4867)} = -2.31$, $p = .021$. The t -value of -2.31 is significant as the p value of .021 is $<.05$. Cohen's effect size value ($d = 0.15$) suggested a small practical significance.

As noted earlier, binary logistic regression was completed on ACT mathematics scores and course completion for computer-based developmental mathematics in order to determine if a relationship between the variables existed. The logistic regression indicated that with an increase in of one interval score on the ACT mathematics test, the odds of completing a computer-based developmental mathematics course decreased by a factor of 0.835.

Summary

The extensive chi-square testing, t -tests, and logistic regression analysis provided abundant information relating to the research questions. In order to reduce the complexity of the testing, a short summary of the research related to the hypotheses is provided.

Research Question 1

Are students who have taken dual enrollment courses in high school more academically successful in a computer-based developmental mathematics courses and programs than students who have not had dual enrollment courses?

A Pearson chi-square analysis indicated dual enrollment courses had no relationship with the grade a student in computer-based developmental mathematics. The same analysis though did indicate dual enrollment is minimally associated to course completion and degree attainment.

In terms of course completion, results of the analysis showed dual enrollment takers tended to complete courses at higher rates and attain degrees at higher rates when taking computer-based developmental mathematics, regardless of the type of dual enrollment course they took. In support of these results, a *t*-test analysis for dual enrollment and ACT mathematics score showed that students who took dual enrollment courses had a mean ACT score that was significantly different than the mean score of those who did not take dual enrollment. A higher ACT mathematics score may suggest that students have completed higher level mathematics courses in secondary school, and therefore, are better prepared for mathematics in higher education. Further investigation that included the introduction of control variables into the chi-square analysis indicated the relationship between dual enrollment and course completion is being influenced by the partial significance of males, black students, and students in their first year, who overall, tend to complete courses at lower rates than other groups.

Pearson chi-square analysis indicated dual enrollment takers tend to attain degrees at higher rates than students who have not had dual enrollment. As with course completion, degree attainment was also analyzed using *t*-testing. Results of the *t*-test indicated the mean degree attainment rate for dual enrollment takers is significantly different than non-dual enrollment takers. The introduction of control variables in the analysis of the two variables indicated white, males and females in their first year of school have a partial significant influence on dual enrollment and degree attainment.

Research Question 2

Are students who live in rural areas academically less successful in computer-based developmental mathematics than students who live in non-rural areas?

Evaluation of student residency was based on the specific research hypotheses associated with research question 2. The research hypotheses only targeted course completion in computer-based developmental mathematics courses and degree attainment in those courses based on whether a student took a course online. The evaluation of student residency did not specifically evaluate grades in computer-based developmental mathematics courses because course grades in computer-based courses are based on pass and no pass. Grades could have been evaluated as in research question one based on scoring a C or better, but passing and not passing is believed to be a nearly equivalent evaluation and is somewhat repetitive.

Pearson chi-square analysis indicated that student residency (non-rural and rural) was significantly related to course completion but degree attainment, based on whether students take at least one course online, indicated student residency is not significant to degree attainment. The analysis indicated rural students pass computer-based developmental courses at higher rates than non-rural students. In support of these results, *t*-tests completed for student residency and ACT mathematics score showed that students who indicated rural residency had a mean ACT score that was significantly higher than the mean score of those who did not take dual enrollment. As indicated previously, a higher ACT mathematics exam mean score may indicate that students are better prepared mathematically, have completed higher level mathematics courses in secondary school, and are better prepared for mathematics in higher education.

Evaluating the course completion association with student residency with the control variables of gender, ethnicity, year in school course taken, and ACT mathematics exam score

showed that these variables had a partial significant relationship between student residency and course completion for students taking computer-based developmental mathematics. The significance in controls was seen for any year in school, for both males and females, and white students. *T*-tests analyses of ACT mathematics exam score evaluation indicated that students from rural areas have higher mean ACT mathematics exam scores and complete courses at significantly greater rates. For year course is taken, rural students complete courses at a higher percentage than non-rural students. Male, non-rural students have a higher percentage rate of non-course completion than completion, while rural females have the highest course completion percentage of any group. Controlling for ethnicity shows that rural whites pass at higher percentage rates than any other group while non-rural black students have the lowest percentage rate, with more not completing than those who complete. Non-rural first year students also have a higher non-course completion percentage than course completion while rural students in all years have the highest course completion percentage.

Research Question 3

Does the curriculum and instruction delivery method used in developmental mathematics have a significant relationship with successful course completion and completion of academic programs of study?

Course completion and degree attainment is significant based on whether the course is taken in the traditional format or the computer-based format. Course completion rates indicate that although more students have gone through the computer-based program and completed courses, course completion percentages are higher for students in traditional programs.

Pearson chi-square analysis of control variables student gender, ethnicity, and year in school course taken, a significant association were found in all groups. Both males and females

showed a significant relationship based on the instructional method with males showing a lower course completion percentage versus passing percentage in computer-based developmental mathematics. Black students were the only ethnicity to show no significance to the association with ethnicity and course instructional method. Black students were the only group to show a lower course completion percentage than passing percentage in both traditional and computer-based courses. The year the course was taken was significant to the course completion and instructional method with all school years showing a higher passing percentage than non-passing percentage.

T-tests completed for traditional courses and computer-based courses with ACT mathematics score showed that students in on-campus and traditional courses had mean ACT mathematics exam scores that were significantly higher than students in online and computer-based developmental mathematics courses. Higher course completion rates were also significantly related to higher mean ACT mathematics exam scores.

Degree attainment analysis for traditional and computer-based developmental mathematics indicated that students in traditional developmental mathematics courses attained degrees at a higher rate than students in computer-based developmental mathematics courses. Pearson chi-square analysis of control variables gender, ethnicity, and year in school course taken, a significant association were found in all groups. Regardless of the control variable, significance was associated between degree attainment and course instructional method. Degree attainment rates regardless of the control variable analyzed, are low. *T*-tests completed for degree attainment indicate mean ACT mathematic scores are significantly related to degree attainment. These results, along with information obtained from the *t*-test for traditional and computer-based developmental mathematics with ACT mathematics score, supports the outcome

of the Pearson chi-square testing indicating that students in traditional developmental mathematics are more likely to attain a degree than those in computer-based courses.

Online and face-to-face courses in computer-based developmental mathematics were also evaluated as part of research question 3 to see if a significant relationship existed between course delivery in computer-based developmental mathematics and course completion. Analysis indicated that students who took computer-based developmental mathematics courses on campus (face-to-face) completed courses at marginally higher percentages than students in computer-based developmental mathematics courses taken online.

Pearson chi-square analysis for the control variables of student age, gender, ethnicity, year in school course taken, and ACT mathematics score was completed to investigate the significance of the controls on course completion in computer-based developmental mathematics based on course delivery method. When controlling for gender, there is a weak significant relationship between online course completion and face-to-face course completion in computer-based developmental mathematics for females. Males tend to not complete courses in both face-to-face and online at higher percentages than the complete but females only fail to complete courses at a higher percentage in online courses. When controlling for ethnicity, there is a weak significant relationship between online course completion and face-to-face course completion in computer-based developmental mathematics for all ethnicities. Online courses have higher non-completion rates across all ethnicities, but black students are the only group to have higher non-course completion percentages in face-to-face courses than their completion percentages. There is also a significant relationship for year in school when taking the course between course delivery and course completion. Independent of year in school the course is taken, course completion percentages are better in the face-to-face courses. Students in taking the course in

their first year have course completion percentages online that are equal to non-completion percentages. Beyond the first year of school, the online course completion percentage drops below the non-completion percentage. *T*-tests of instructional method and degree attainment also indicate that on-campus students that took face-to-face traditional courses had significantly higher mean ACT mathematics exam scores than students in online courses, and that mean ACT mathematics exam scores were significantly related to higher degree attainment.

Evaluation of ACT mathematics exam scores for students in developmental mathematics indicated that with higher ACT mathematics exam scores, the probability of finishing a course or obtaining a degree decreased. It appears as though a factor other than mathematical ability is causing students to not complete the needed developmental mathematics courses.

CHAPTER V: SUMMATION OF RESEARCH

Developmental mathematics programs at community colleges serve as an important part of the higher education system. These programs provide many underprepared students the foundation of mathematical skills that enables them to move on to college-level mathematics coursework (Community College Research Center, 2014). Although not always a necessity for many students in community colleges, college-level mathematics is often a necessary but difficult obstacle for students to overcome before they can achieve their higher education and career goals (Bonham & Boylan, 2012). Many students who are underprepared for higher education and require developmental work to accomplish their academic and career goals are unsuccessful in overcoming the obstacle of developmental coursework (Bahr, 2008; Boatman & Long, 2010). The importance and necessity of developmental mathematics, although argued by some to be a financial burden and not appropriate to be placed in higher education (Bahr, 2008; Oudenhoven, 2002), is needed if higher education opportunities are to be available to all people regardless of educational preparedness. As Oudenhoven (2002) emphasized, developmental programs not only help solve the educational deficiencies of many students in higher education but they also may aid in diminishing social inequalities and improve the economic health of the nation.

In higher education, the open enrollment policies of community colleges create an educational environment where many of the students are underprepared for higher education. Offering developmental courses for the large, underprepared student populations at community colleges should be a matter of choosing equitable education for all students rather than a choice based on financial burden or appropriateness. The lack of success of developmental programs,

but the necessity to have these programs, has facilitated the need of developmental course and program redesign in many community colleges (Ariovich & Walker, 2014).

The lack of college-level readiness of students entering higher education can be found in any subject but overall, mathematics deficits for large populations of beginning higher education students is especially prevalent (Bonham & Boylan, 2012). As stated earlier, 42% of students starting college or university are not prepared to take college-level mathematics courses and therefore, are often required to enroll in developmental mathematics courses (National Center for Education Statistics, 2012). The majority (82%) of two-year college students enrolling in developmental mathematics courses never earn a degree or certificate, or transfer to university (Bahr, 2008). This lack of student success in developmental mathematics programs, the large number of underprepared students needing developmental mathematics courses, and the financial burden of these programs to schools has necessitated the redesign of developmental mathematics courses (Bailey, Jeong, & Choo, 2010; Cafarella, 2016a; Community College Research Center, 2014).

Although the redesign of developmental mathematics programs in both 2-year and 4-year higher education institutions vary widely, many developmental mathematics program redesigns have included (a) avoidance methods, which are different types of educational interventions used to help students avoid taking developmental mathematics courses; (b) acceleration methods, which are used to accelerate students through the required developmental mathematics courses, and (c) contextualization methods, which involve creating developmental mathematics courses that are designed to target specific areas of student study.

This research specifically looked at a redesigned developmental mathematics at Heartland Community College in Normal, Illinois, that was implemented in Fall 2012 as a self-

paced, computer-based instructional program that affords students the opportunity to accelerate through their required developmental mathematics courses. In addition to the developmental mathematics redesign, the college also offers dual enrollment courses that allow students to take college enrollment courses while still in secondary school; prior to them actually enrolling in the college. Through the dual enrollment program, students can avoid or reduce the number of developmental mathematics needed in college by taking college enrollment courses while still in high school. Dual enrollment courses not only offer college enrollment courses that help student avoid specific college courses and accelerate their pace through school, but the courses also help prepare students mentally for the higher education environment.

With the developmental mathematics program being computer-based, the impact on students through the use of technology was also investigated as a possible impact on students successfully passing courses and obtaining degrees. Student successful completion of courses and degree obtainment in computer-based courses developmental mathematics compared to those in traditional lecture-based instruction in developmental mathematics courses. In addition, the effect of taking a courses online were analyzed to see if online delivery had an impact of students successfully completing courses and obtaining degrees. The effect of computer-based developmental mathematics on the rural learner was also compared to non-rural learners to see if living in a rural area where technology infrastructure may not be equivalent to non-rural areas had an effect on course completion and degree attainment.

Discussion

Using Tinto's (1993) *Longitudinal Model of Individual Departure from Institutions of Higher Education* as the theoretical approach to evaluating the research questions. The basis of Tinto's theory is students in higher education will be encouraged to persist in their education if

they are integrated both academically and socially into the institution (Tinto, 1975, 1993, 2006). Students are strongly influenced by varying individual social, economic, cultural, and academic background characteristics that create both benefits and detriments to their pursuits in higher education (Tinto, 1975, 1993, 2006). The research questions in this study looked at some varying student characteristics, such as gender, age, ethnicity, year in school, where students live, and preparedness for higher education, and how these characteristics are related to taking developmental mathematics in the traditional classroom, through computer-based instruction, and through online instruction. The three research questions, results of statistical testing, and interpretations of the results are included below:

Research Question 1

Are students who have taken dual enrollment courses in high school more academically successful in computer-based developmental mathematics courses and programs than students who have not had dual enrollment courses?

The first question research question was used to address whether dual enrollment courses, which are used to prepare students academically by offering students college enrollment courses while still in high school, were studied to see if students who had dual enrollment courses, regardless of type of course, appeared to be better prepared for college study. Although many students who take dual enrollment mathematics courses in high school are assumed to be at a college-level mathematics level when beginning college and not needing developmental mathematics courses, dual enrollment courses of any type taken in high school have been reported to improve student performance in college (Community College Research Center, 2012).

Pearson chi-square analysis of the grades, course completion rates, and degree attainment for developmental mathematics students who had taken dual enrollment and non-dual enrollment takers were investigated. Results of the analysis indicated dual enrollment students taking developmental mathematics have better course passing and degree attainment rates than their peers who had not taken dual enrollment courses but there was no significant relationship between dual enrollment and course grades in computer-based developmental mathematics.

The percentage of developmental mathematics students who took at least one dual enrollment course had a course pass rate of 57.3%, while the pass rate for those not having taken a dual enrollment course is 52.9%. The Pearson chi-square analysis indicates that students who took dual enrollment courses, regardless of dual enrollment course type, were more likely to complete developmental mathematics courses. Degree attainment for developmental mathematics students who took at least one dual enrollment course attained Associates' degrees at a 25.1% rate, while those who had not taken a dual enrollment course the rate was 17.1%. The Pearson chi-square test indicates developmental mathematics students who had taken dual enrollment courses were more likely to attain associate degrees than those students who have not had dual enrollment courses.

T-tests completed for dual enrollment and ACT mathematics score showed students who took dual enrollment courses had a mean ACT score that was significantly higher than the mean score of those who did not take dual enrollment. In addition, the standard deviation of scores for dual enrollment student ACT mathematics scores were less than their peers who did not take dual enrollment courses. The ACT mathematics *t*-test indicated that students who have taken dual enrollment courses were better prepared for mathematics in higher education, and that those who were better prepared for mathematics, tended to enroll in dual enrollment programs and pass

courses at higher rates than their peers. The results of the *t*-tests indicated students who took dual enrollment courses were those students who may have had higher aspirations' for enrolling in higher education, and therefore were motivated to do well once in college.

Further investigation that included the introduction of control variables into the chi-square analysis and *t*-tests indicated the relationship between dual enrollment and course completion was being influenced by the partial significance of male, black students in their first year, who overall, tended to complete courses at lower rates than other groups. These results were probably an indication of the lower success rate of school systems often associated with areas of higher populations of marginalized ethnicities.

Research on the relationship between dual enrollment courses and student success in developmental mathematics is minimal. The results of this research support those found by the Community College Research Center (2012) in studies of colleges in Florida, New York City, and California that found dual enrollment courses were a positive influence on college students. The Community College Research Center (2012) research showed dual enrollment students tend to remain in college, earn more college credits, and maintain a higher grade point than their non-dual enrollment taker peers. These results are consistent with research that indicates dual enrollment students are more likely to remain in college than students who have not had dual enrollment (Community College Research Center, 2012; Kim & Bragg, 2008; Rutschow & Schneider, 2011).

Research Question 2

Are students who live in rural areas academically less successful in computer-based developmental mathematics than students who live in non-rural areas?

The second research question was developed in order to compare the academic success of students in rural areas versus students in non-urban areas that are taking computer-based developmental mathematics. As Cejda (2010) pointed out, many rural students suffer from a lack of modern technological infrastructure to support online learning. Although computer-based developmental mathematics at Heartland Community College is considered a traditional course when taken on the college campus, students can do extensive amounts of work from home by using the internet to access the modularized computer-based curriculum. Research question 2 was used to investigate the impact of the lack of technological infrastructure on rural learners taking courses with extensive amounts computer-based, internet work.

The results of the Pearson chi-square analysis indicated 51.2 % of non-rural students completed computer-based developmental mathematics courses while 57.8% of rural students completed courses. Pearson chi-square analysis of degree attainment and student residency though were unrelated.

These results indicated students in rural areas were not impacted by a technological barrier, and that rural students, may have been better academically prepared than their non-rural peers. Independent samples *t*-tests on ACT mathematics score and student residency indicated there was a significant difference between the mean scores of rural students and non-rural students. With the computer-based course not being investigated based on delivery method (traditional and online), rural students having been academically underprepared in comparison to non-rural students, as noted in research by Cejda (2010), and Leist and Travis (2010), was not

seen in this research. Residency was shown to be related to course completion in computer-based developmental mathematics and the results of *t*-testing indicated that those taking computer-based developmental mathematics and lived in rural areas were better mathematically prepared than their non-rural peers.

Analysis of the control variables appeared to show course completion was associated with student residency when including the control variables of gender, ethnicity, year in school the course is taken, and ACT mathematics score. Significance in controls was noted for students in any year of school, both males and females, white students, and those who score higher on their ACT mathematics test.

The analysis of controls indicated that several control variables were significant in the course completion rate of students based on residency, but there appeared to be a connection between the controls that were causing the significance to appear. When looking at the influence of the controls, there was a drop in course completion for students from non-rural areas, male, black, and with lower scores on the ACT mathematics test. The significance in course completion and residency appeared to be strongly influenced by non-rural black males, students with lower ACT mathematics exam scores, and first year students. Although the research was initially investigating the influence of technological infrastructure in rural areas and its impacts on students in computer-based mathematics, the results of the analysis indicated factors other than technology were a stronger influence for course completion in computer-based developmental mathematics.

Research by the American Association for Community Colleges (2016a) indicates 22% of full-time students and 41% of part-time students are employed full-time, and 44% of full-time and 32% of part-time students are employed part-time. As Tinto (1993) theorizes, being

employed is generally harmful to higher academic success for students, and full-time employment is clearly more harmful than part-time employment. Tinto (1993) also points out that the view of the employer on college attendance plays a critical role in student persistence. The demands of work on student time, especially those of lower economic status, means students have less time to spend on their studies. Although lower economic status is not controlled by rural and non-rural residency, the research showed higher populations of marginalized students which are often of lower economic status. It appeared as though the results of this research indicated a drop in course completion for students from marginalized populations that often struggle financially, and are swayed in their academic decision making based on those struggles (Tinto, 1993).

Controlling for ethnicity showed that rural whites passed at higher percentage rates than any other group, while non-rural blacks had the lowest percentage rate of students based on ethnicity who were completing courses. Black students are under-represented as a group in higher education. As stated by Tinto (1993), “under-represented students, as a group, are more likely to come from disadvantaged backgrounds and to have experienced inferior schooling prior to college” (p. 73). If black students in the sample were underprepared, the significance of lower ACT mathematics scores contributing to non-course completion could have weighted strongly towards this group. Theory suggests that the lack of preparedness for blacks is a major contributor to more black students not completing courses than complete (Tinto, 1993). This research results also showed rural students completed courses at higher rates than non-rural students, and for the sample studied, black students were predominately represented in the non-rural portion of the sample. It appeared as though the non-rural black students, who may have

been underprepared academically, may have been a factor influencing the higher completion rate on rural students.

Lack of preparation for black students though may not have been the only factor influencing their success in completion of computer-based developmental mathematics courses. Academic integration into higher education appears to be more important to black students than it is to white students (Tinto, 1993). The design of computer-based instruction in developmental mathematics, where there is less involvement in the classroom among peers and instructors, may have substantial negative influence on black students who may already feel isolated and marginalized in predominantly white higher academic institutions (Tinto, 1993). The isolation that may be felt by black students in computer-based developmental mathematics courses may not be experienced as strongly by other ethnic groups, especially white students, but the lack of social and academic involvement with students and instructors still impacts those groups (Tinto, 1993). As Tinto (1993, 1999, 2006) pointed out, the lack of social and academic involvement in the classroom has an especially negative influence on commuter campuses, typical of community colleges.

Research Question 3

Does the curriculum and instruction delivery method used in developmental mathematics courses have a significant relationship with successful course completion, sequence completion, and completion of academic programs of study?

The Pearson chi-square analysis indicated that within the entire data set of developmental mathematics student who passed courses at Heartland Community College, 42.5% were in traditional courses while 57.5% were in computer-based courses, which indicated that more students had completed computer-based developmental mathematics courses. When looking at

traditional developmental mathematics and computer-based developmental mathematics separately, the passing percentage in traditional mathematics was 59.9% while 53.1% in computer-based. The Pearson chi-square analysis indicated that students who took traditional developmental mathematics courses completed courses at a rate 6.8% higher than developmental mathematics students who were in computer-based courses.

Results of analysis for research question three indicated that there was a significant relationship between course completion and degree attainment dependent on whether the course was in the traditional face-to-face format or in the computer-based format. Analytical results of course completion in traditional and computer-based developmental mathematics indicated that computer-based instruction in developmental mathematics at Heartland Community College showed an increase in the percentage of number of students completing developmental mathematics, but this was due to the larger time frame for computer-based courses used in the study. In terms of equivalent numbers of students who took courses and completed courses in developmental mathematics, traditional face-to-face developmental mathematics courses at Heartland Community College had a higher percentage of completion. The rate of course completion in computer-based developmental mathematics was 53.1%, while traditional developmental mathematics course completion was 59.9%.

Higher course completion rates in traditional face-to-face developmental mathematics courses versus computer-based courses is supported by the research of Ariovich and Walker (2014). Ariovich and Walker (2014) found that students in traditional developmental mathematics courses passed courses at higher rates than students in computer-based developmental mathematics courses. Initially, Ariovich and Walker (2014) found a course completion rate of 37% in traditional developmental mathematics courses in comparison to a

28% passing rate in computer-based courses. In addition to Ariovich and Walkers (2014) research, Zavarella and Ignash (2009) found computer-based developmental mathematics instruction negatively impacted completion rates due to the high number of student withdrawals.

Contrary to the results of course completion noted in this research, Cafarella (2016a) found computer-based developmental mathematics increased student completion rates. Cafarella (2016a) cited two studies, one at Cleveland State Community College (CSCC), in Cleveland, Tennessee, and one at the Community College of Denver (CCD), where modularized, computer-based courses increased the passing rate of students in comparison to traditional mathematics courses. Rutschow & Schneider (2011) also cited two programs, Foothill Community College and Jackson State Community College, where modularized computer-based developmental mathematics programs improved student completion. Neither Rutschow and Schneider (2011) or Cafarella (2016a) indicated whether withdrawal rates from courses were used in the analysis of the passing rate of students. In this research, withdrawal was considered non-passing, or non-completion, so students who were recorded in the data set as withdrawn were included in the analysis. If withdrawals were eliminated from the analysis of course completion in traditional and computer-based developmental mathematics, and Ariovich and Walkers (2014) research is correct in that more students withdraw from computer-based courses, course completion rates in computer-based developmental mathematics would have appeared to be better.

To further investigate the apparent relationship between course completion and the instructional delivery used in developmental mathematics in this research, *t*-testing was conducted to determine if course completion in traditional and computer-based developmental mathematics courses differed depending on student ACT mathematical exam scores. Higher ACT scores for students taking courses may indicate that students have a stronger foundation in

mathematics. For students in the sample, results indicated students who took traditional developmental mathematics courses had significantly higher mean ACT mathematics test scores than those students who had taken computer-based developmental mathematics. These results appeared to indicate that developmental mathematics students in traditional developmental mathematics may have been better prepared for mathematics, and therefore had better course completion rates. The results of this research indicating higher completion rates in traditional developmental mathematics courses appeared to be partially based on cognitive skills rather than course instructional method.

The results of this research on course completion were similar to results report by Booth et al. (2014). Booth et al. (2014) reported that accelerated developmental mathematics students that are lower achieving are better supported in traditional developmental mathematics courses. In this study, course completion rates for computer-based developmental mathematics students had lower mean ACT scores, and those lower scores may have had a negative influence on the rates of course completion.

Pearson chi-square analysis when controlling for gender, ethnicity, year in school course taken, and ACT mathematics exam score it appeared that black males struggled more than other ethnic groups in both developmental mathematics course types. Blacks in both traditional and computer-based developmental mathematics had a larger percentage of non-completers than completers. In addition, when looking at ACT mathematics exam scores, better course completion rates were indicated with higher ACT mathematics scores. When looking at gender, males had more non-completers than completers in computer-based developmental mathematics. The analysis seemed to indicate that black males, who were underprepared in mathematics, needed the most support in developmental mathematics courses.

In the Pearson chi-square analysis of degree attainment for students who had completed traditional or computer-based developmental mathematics courses indicated that students who took traditional developmental mathematics course obtained degrees at higher percentages than students who took computer-based developmental mathematics courses.

When analyzing degree attainment and course instructional method, controls were also introduced to analyze the impact of those controls on the outcomes of the prior analysis. Pearson chi-square analysis of control variables gender, ethnicity, and year in school course taken, and ACT mathematics score, a significant association was found in all groups. No one control variable appeared to have been having a stronger influencing effect on the percentage of students obtaining degrees in either traditional or computer-based developmental mathematics. Degree attainment rates, regardless of the control variable analyzed, were low. Traditional developmental mathematics courses had a degree attainment percentage rate of 27%, with computer-based developmental mathematics at 18%. Although the degree attainment rates associated with each type of developmental mathematics course design appeared very low, Bahr (2008) noted that many students in community colleges are underprepared for higher education and are enrolled in college as an experiment, and that the likelihood of favorable outcomes become negatively impacted.

T-testing of ACT mathematic exam scores and students who took developmental mathematics, regardless of course type, indicated that students with higher ACT mathematics exam scores obtained degrees at a higher percentage than students with lower ACT mathematics exam scores. The *t*-test results, along with Pearson chi-square results, indicated that traditional developmental mathematics students who had higher ACT mathematics exam scores, obtained associate degrees in higher numbers than their lower ACT mathematic exam scorers in those

courses, but in computer-based developmental mathematics, higher ACT mathematic exams scorers also obtained degrees at higher rates than their counterparts with lower ACT mathematics scores. Results of this study indicated that completion of developmental mathematics courses and obtaining a degree may have been related more to secondary school mathematics preparation than to the instructional method used in the course.

Additional analysis of the relationship between ACT mathematics exam scores and degree attainment was completed. In addition to the Pearson chi-square analysis and *t*-testing, degree attainment of developmental mathematics students and ACT mathematics exam scores were explored using binary logistic regression analysis. Results of the analysis indicated that students who took developmental mathematics in both traditional and computer-based courses, were less likely to obtain a degree as their ACT mathematic exam scores increased. It appears as though students who took developmental mathematics courses at Heartland Community College between Fall 2012 and Spring 2016, and higher ACT mathematics exam scores, left the college before obtaining a degree. Although a definitive reason why higher ACT mathematics exam scoring students were less likely to earn a degree, if one considers the demographics of many community college students, it may be that higher scorers are moving on to four-year universities prior to completing their degree.

As part of the evaluation of research question 3, online and face-to-face courses in computer-based developmental mathematics were evaluated to find if a significant relationship between course delivery method in computer-based developmental mathematics and course completion existed. A weak significant association between course delivery method and course completion was found. Pearson chi-square analysis indicated that students who took computer-based developmental mathematics courses on campus (face-to-face) completed courses at

marginally higher percentages than students in computer-based developmental mathematics courses taken online. This outcome is consistent with research that indicates face-to-face courses support developmental students better than online courses (Ashby, Sadera, & McNary, 2011; Zavarella & Ignash, 2009). Zavarella and Ignash (2009) indicated that a major impact to course completion in online developmental mathematics courses was due to high withdrawal rates, the perception of personal learning needs, time commitment, and their personal best learning styles. Zavarella and Ignash (2009) indicated that positive outcomes for developmental students in online computer-based course are possible but increased student supports are needed. This research appeared to indicate computer-based instruction in a face-to-face format offered more support to developmental mathematics students, and therefore had increased course completion rates in comparison to online courses.

A *t*-test of course delivery method and ACT mathematics score was completed to find if the mean ACT mathematics score for developmental mathematics students in online computer-based developmental mathematics courses differed from face-to-face students and may have had an influence on course completion rates. The results of the *t*-test indicated the mean ACT mathematics score for students who took online courses were significantly higher than those who took face-to-face courses. The practical significance in the mean difference in ACT mathematics exam scores between online and face-to-face students though was small. The sample size and the small mean difference between student ACT mathematics exam scores probably indicated that the apparent mathematic preparedness of developmental mathematics students did not play a significant role in course completion in the difference between online and face-to-face computer-based courses.

Pearson chi-square analysis for the control variables of gender, ethnicity, year in school course taken, and ACT mathematics score was completed to investigate the significance of the controls on course completion in computer-based developmental mathematics based on course delivery method. Significance was seen in each control variable, but a few control groups appear to be more strongly influenced in their course completion based on the delivery method. A substantial increase in non-course completion versus course completion was indicated for males and black students, with a higher percentage of non-completers indicated in both face-to-face and online courses for those groups. As in previous analyses, results indicated black males who were struggling in developmental mathematics, whether in the traditional or computer-based instructional format. As cited previously, Tinto (1993) indicated that blacks are more likely to come from disadvantaged backgrounds and have been educated in inferior schools. In addition, as noted previously, the age typical of college students is often a time in a student's life when external obligations of work, due to an unstable financial situation, influence their obligations to studies. Results of the control variable analysis seemed to indicate that online computer-based developmental mathematics course did not support students as well as face-to-face computer-based developmental mathematics students. The analysis also indicated students from disadvantaged backgrounds needed additional or different types of academic and social supports than were offered.

Findings

The major findings based on hypotheses testing indicates:

1. *Student persistence through both computer-based and traditional developmental mathematics courses appears to negatively impact student retention through to obtaining a degree.*

This finding is supported by research of developmental mathematics programs in higher education. Research has shown that student success in courses and retention to completion of college is adversely impacted when developmental mathematics coursework is a necessity (Ariovich & Walker, 2014; Bahr, 2008; Bonham & Boylan, 2012; Cafarella, 2016a; Community College Research Center, 2014; Rutschow & Schneider, 2011; Zientek, Skidmore, Saxon, & Edmonson, 2015). Students who place into developmental mathematics courses may have several semesters of non-credit, financially straining coursework to complete prior to being able to enroll in courses that offer college credit. As Hern (2012) noted, two-year college students required to take developmental mathematics courses are less likely to complete college-level mathematics, obtain a degree, or transfer to university. The results of this research support the results of much of the research on developmental mathematics in community colleges.

2. Self-paced, computer-based instruction in developmental mathematics does not support developmental mathematics students as well as traditional developmental mathematics courses, especially when it comes to the least mathematically prepared students.

Passing rates and degree attainment rates for developmental mathematics students have decreased at Heartland Community College since the implementation of computer-based developmental mathematics. Self-paced, computer-based instruction offers a great opportunity to students who are self-motivated and mathematically prepared. Results from the analysis of ACT mathematics exam scores indicates that students who were most successful in completing courses and obtaining degrees increased with an increase in the ACT mathematics exam scores. Those students though that are typical of developmental mathematics courses are often those who lack self-motivation and are academically underprepared. Expecting students who lack self-

motivation and are academically underprepared to complete developmental mathematics courses at their own pace using computer-based instruction seems to be contradictory to the purpose of developmental mathematics instruction. As discussed by Cafarella (2016b), a developmental course that uses acceleration is not best practice for lower academically performing students and is most suited for students who require minimal support. In addition, as Epper and Baker (2009) indicated, there is a 25% occurrence of registered learning disabilities in lower-level developmental mathematics students, with as many as 70% when including students that are unreported. Expecting students with learning disabilities to self-regulate their mathematics learning is not practical, and the results of this study appear to support that contention.

3. Black students appear to be the least prepared in mathematics when compared to other ethnicities, and are not well supported by computer-based or traditional developmental mathematics courses in terms of course completion and degree attainment.

Bailey, Jeong, and Choo (2010) indicated in research of Achieving the Dream colleges, that black students referred to developmental mathematics need more courses of developmental mathematics than their student counterparts. Bailey, Jeong, and Choo (2010) noted “that the odds of African-American students passing to a higher level of developmental math were 0.67 – 0.91 times the odds of their White peers. In this study, black students appeared to be the most negatively impacted by developmental mathematics regardless of instructional method. The analysis of student data in this study showed blacks did not complete courses or obtain degrees at rates comparable to other ethnicities. In addition, analysis of ACT mathematics exam scores and ethnicity indicated that black students tended to score lower and were less prepared for developmental mathematics coursework. The analysis of ACT mathematics exam scores, although not a direct indicator of developmental mathematics placement, indicated that more

black students, as an ethnic group, were placed into developmental mathematics sequences, placing them at a greater risk of failing to complete courses and obtain degrees. As Hern (2012) noted in research, the more exit points allotted by multiple semesters of developmental coursework, contributes to attrition from developmental course sequences.

If research by Hern (2012) is accurate, acceleration methods such as computer-based developmental mathematics using modularization should reduce the amount of time a student needs to complete a developmental sequence. It appears from the results of this study, that black student course completion rates improved slightly with the implementation of the redesign of developmental mathematics from traditional face-to-face courses to computer-based instruction, but the completion rates are minimal.

But many developmental students, especially those from underrepresented groups, have specific non-academic social and cultural factors that negatively impact their integration to college, which in turn negatively impacts their ability to be successful academically (Booth et al., 2014; Zavarella & Ignash, 2009). Even though this study indicated that Black students were slightly more successful in computer-based developmental mathematics courses, completion of courses and obtaining a degree for Black students, regardless of instructional method, was worse in comparison to other ethnicities. It appears as though something more than mathematic ability was impacting Black students in developmental mathematics.

4. Dual enrollment courses taken by high school students appear to be better supporting the higher achieving students and not reaching the lower achieving students who would benefit the most from the program

Many dual enrollment programs that community colleges undertake with secondary schools require students to have a specific minimum grade point average to enroll in a dual

enrollment course. With community colleges having an open door enrollment policy, having a minimum grade point average requirement for students to take a course appears to be contrary to a central mission of community colleges to make higher education available to all.

Analytical results obtained in this study for dual enrollment indicated that students who took dual enrollment courses were better academically prepared, completed developmental courses at higher rates, and obtained degrees at higher rates than students who did not take dual enrollment courses. The results in this study were not surprising considering that it appears as though higher achieving students in high school are those who are enrolling in dual enrollment courses. As Prelow and Wathington (2014) indicated in their research, preexisting characteristics of a student, such as academic preparedness and motivation, may actually be the sole determining factor of student academic success in college, not their participation in dual enrollment courses.

5. Computer-based developmental mathematics student course completion is least supported by developmental mathematics courses that are delivered online

Results of this study showed that online computer-based developmental mathematics did not support student course completion as well as computer-based developmental mathematics taken on-campus. The results of this study are consistent with much of the research on distance learning that include student attrition in the analysis (Ashby, Sadera, & McNary, 2011) (Zientek, Skidmore, Saxon, & Edmonson, 2015). It is generally accepted that students who are successful in online courses are self-motivated to succeed and capable of managing their time in order to become independent in their learning. Many of the students enrolled in developmental mathematics are underprepared academically. As stated previously, computer-based instruction that is self-paced may offer a great learning opportunity for students who are self-motivated and

mathematically prepared, but for those who are underprepared academically, self-paced learning is not best practice (Cafarella, 2016b). With the addition of online learning in computer-based developmental mathematics instruction, the increase of student non-completion courses should be expected. The addition of online courses to developmental mathematics programs, regardless of delivery method, seems to undermine the purpose of developmental mathematics.

6. Rural students complete computer-based developmental mathematics courses at higher rates than their non-rural counterparts due to the higher population of underrepresented ethnicities in non-rural areas.

Rural technological infrastructure appeared to not be a diminishing factor in student academic success for students taking computer-based developmental mathematics course in this study. Analysis of student data indicated that rural students completed courses at higher rates in computer-based developmental mathematics than non-rural students.

The student record data for computer-based developmental mathematics students, indicated that approximately 37% of students who took computer-based developmental mathematics reported a rural home address and 10% of all students took courses online. With such low numbers of rural students having relied on internet access to complete online courses, the lack of modern technological infrastructure that could have potentially impacted student learning that is noted in research by Cejda (2010), was most likely not influencing the outcomes of the statistical analysis.

A significant difference in the mean ACT mathematics exam scores for rural and non-rural students did exist and may have been a dominant determining factor for higher course completion and degree attainment rates for rural students. When analyzing the ethnic profile of rural and non-rural students, it was not surprising that a larger population of underrepresented

students existed in non-rural locations. Although not always the case, many underrepresented groups often are academically underprepared due to inferior secondary education (Tinto, 1993). The analysis of ACT mathematics exam scores for the differing ethnic groups in this study indicated that the ACT mathematics scores were significantly lower for black students. With the majority of black students having indicated a non-rural address, and having had lower course completion rates and lower ACT mathematics exam scores than other ethnic groups, it is likely that the population of black students in non-rural areas were diminishing the course completion rates overall for non-rural students.

Recommendations

Based on the findings of this study, and a review of associated research, there are several recommendations that may better support student success in developmental mathematics that can be made.

The study indicated dual enrollment students are better mathematically prepared based on ACT mathematics exam scores than their non-dual enrollment counterparts. It appears as dual enrollment courses are taken by students who are academically better prepared in mathematics, and therefore would be expected to do better in developmental mathematics even without dual enrollment. In addition, in terms of ethnicity, black students appear to be the least prepared in mathematics and successful in developmental mathematics courses independent of instructional method.

As indicated by the Community College Research Center (2012), many dual enrollment programs target students who are higher achieving and have higher grade point averages. If dual enrollment is going to make a substantial difference in the success of college students, underrepresented student populations that are typical of underprepared populations in higher

education need to be targeted as the students who need dual enrollment courses. In this study, the analysis indicated only 5.2% of students had a dual enrollment course, and of that sample only 0.2% were black, and 0.4% were other non-white ethnicities. Yet when looking at the developmental mathematics sample group, blacks mean ACT mathematics scores were lower and they were the least successful in completing developmental mathematics courses and obtaining degrees. This information indicates that as a group, blacks could benefit from taking dual enrollment courses that help them prepare for college or enables them to avoid having to take developmental mathematics. It is recommended that dual enrollment programs should target blacks and other underrepresented student populations in high school in order to improve the overall success of students in college, and success in developmental mathematics.

Dual enrollment courses should be offered on-campus rather than at the high school in which the student enrolled. Research has shown that in order for dual enrollment to have an effect on student enrollment in college and degree attainment, student need to take dual enrollment on college campuses (Community College Research Center, 2012). Research has shown there is no significant improvement in college success for students who take dual enrollment courses on high school campuses (Community College Research Center, 2012). The research of the Community College Research Center (2012) appears to indicate dual enrollment courses held on-campus helps students separate themselves from the institution of the past and integrate to the institution of the future. As Tinto (1993) pointed out, the mental preparation for higher education requires one to separate from communities of the past and begin the “adoption of behaviors and norms appropriate to the life of the college” (p.95). Tinto (1993) also indicated the importance of integration to higher education can be especially important to underrepresented or marginalized students beginning college.

Targeting marginalized student populations can be difficult for some community colleges though because community colleges do not control the demographic profile of the students in the district they serve. Regardless though, students representing marginalized population usually do represent a portion of any secondary school found within a community college district, and a concerted effort to target those groups should be a goal of dual enrollment programs. The positive effects of dual enrollment on developmental mathematics student course completion and degree attainment rates may improve significantly with an increased effort to recruit and enroll marginalized student groups.

The results of the study indicate that the majority of students taking developmental mathematics courses complete courses and obtained degrees at higher rates in traditional face-to-face developmental mathematics courses rather than in self-paced, modularized computer-based developmental mathematics. As research has shown that there is no significant difference in mathematics achievement based on whether developmental mathematics is offered in the traditional face-to-face format or in the computer-based format (Hodara & Columbia University, 2011; Ye & Herron, 2010; Zavarella & Ignash, 2009; Zientek et al., 2015). Withdrawal rates from computer-based developmental mathematics courses, especially online courses, is higher than in traditional courses (Zavarella & Ignash, 2009).

One factor that effects student learning when using computer-based learning formats, regardless of course type, is the personal motivation to complete the work (Zavarella & Ignash, 2009). As pointed out by Bahr (2008), many underprepared students at community college attend school as a test, and due to the indifference in attitude, personal motivation can suffer. With a lack of self-motivation in underprepared students in community colleges, and the majority of developmental mathematics students being underprepared, a developmental

mathematics program that relies solely on self-paced learning seems self-defeating.

Additionally, research has shown that many students are uncomfortable with working on computers for their coursework and that instructors were better at explaining mathematics problems and ideas (Zavarella & Ignash, 2009).

It appears computer-based instruction in developmental mathematics should be used as a supplement to traditional face-to-face courses. Student learning in both computer-based and traditional developmental mathematics courses is nearly equivalent, but withdrawal rates in these courses is resulting in diminished academic student success. With a lack of intrinsic motivation and self-regulation being a major cause of withdrawal, students may need more contact and interaction with other students and faculty, both socially and academically, to be academically successful (Tinto, 1993). As Tinto (1993) pointed out, in commuter colleges there needs to be “1) the construction of classroom communities; 2) the strengthening of the student and faculty communities within the college; 3) bridging the gap between the world of college and external communities; and 4) the timely provision of services to students” (p. 192).

The lack of success indicated in this research for black students in both traditional and computer-based programs appears to indicate that a traditional face-to-face developmental mathematics course supplemented by computer-based instruction is not going to improve the success of black students. As indicated in research by Booth et al. (2014) and Zavarella & Ignash (2009), developmental students often have cultural-specific factors that impact their ability to be successful in a course that is independent of cognitive skill. It is recommended, based on the results of this study, that developmental mathematics should offer students a variety of supports based on the demographic profile of the students attending the institution. Offering skills building courses that enable students to develop skills in time management, organization,

and studying (Booth, et al., 2014). In addition, developmental students from marginalized groups would benefit both academically and socially from the creation of cohorts, or learning communities of students, with similar educational goals, cultural backgrounds, and social interests (Rutschow & Schneider, 2011; Tinto, 1993).

Lastly, it is recommended that developmental mathematics students taking courses online be communicated with by the school, before the semester begins to discuss the requirements needed for successful online learning, be provided equivalent, not equal, opportunity to academic support through both tutoring and instructional support, be frequently monitored and informed of their academic progress, and be provided early interventions when necessary. Zavarella and Ignash (2009) noted students withdrew from online developmental mathematics courses due to their personal misconception of learning need and of what was expected from them in an online course. As mentioned above, developmental students often have cultural-specific factors that impact their ability to be successful in a course that is independent of cognitive skill (Booth, et al., 2014; Zavarella & Ignash, 2009), if students are informed of the time and learning commitments of an online course, afforded equivalent academic support provided to on-campus students, communicated with frequently with feedback and guidance, and given support when the need arises, student success in online developmental courses may improve.

Future Research

One objective of developmental mathematics programs is to develop the mathematical skills of underprepared students to a level that enables them to successfully migrate into college-level mathematics courses and achieve their academic goals. Even with the well intentions of developmental mathematics programs, most appear to be detrimental to underprepared student success in higher academia (Bahr, 2008). The continued research on how to overcome the

detrimental effects of developmental mathematics programs that they impose on developmental students is apparent.

As Bahr (2008) pointed out, the largest percentage of students beginning community college who enroll in mathematics, enroll in developmental courses, and those who are successful in completing the needed developmental coursework, are those who appear to need the least help. Longitudinal research on how to reduce or eliminate the barrier created by developmental coursework, especially for the least academically prepared student, is a necessity for community colleges if solutions to solving the problem is hoped. With the open door enrollment policies of community colleges, underprepared students will always be some portion of the student population. Well designed, successful developmental mathematics programs, that serve the most underprepared students in higher education, would have a powerful effect on a countless number of struggling community college students.

With the withdrawal rates being extremely high in developmental mathematics courses, qualitative research on the external factors that cause developmental mathematics students to withdraw from courses and college would be beneficial to discovering the non-academic that are negatively influencing students. Quantitative research can guide the qualitative research. Quantitative analysis in a study can tell you what happened, but qualitative research helps to inform as to why something happens. Qualitative research in developmental mathematics programs can help determine why students fail or withdraw from a developmental mathematics course and what higher education institutions can do to reverse the impacts.

Another area of future research could look further at the degree attainment rates of developmental mathematics students in community colleges. Often the success of developmental mathematics is measured by students advancing from developmental courses into

college-level mathematics courses and, as in this study, degree attainment. An issue with using either of these methods as a measurement of student success is the non-graduating community college student who moves on to a career, different community college, or four-year university prior to obtaining a degree or enrolling in a college-level mathematics course. Future research should attempt to track a cohort of non-degree receiving developmental mathematics students, transferring to other community colleges or four-year universities, to determine the real impact of developmental mathematics on the academic success or failure of those students.

Dual enrollment courses have been shown to promote enrollment into higher education, help students attain a higher GPA, and encourage retention in college (Community College Research Center, 2012). Dual enrollment courses though have also shown that the success of students who go through dual enrollment courses is related to whether the course given on a college campus or within a secondary school (Community College Research Center, 2012). The results from this study indicate that dual enrollment courses taken on college campuses by developmental mathematics students are associated with the success of the student in developmental mathematics. Future research could continue to explore the cited differences of college success for students who take dual enrollment courses on college campuses versus those students who take dual enrollment courses in secondary schools.

Concluding Remarks

Developmental mathematics in community colleges across the nation offer a gateway to many underprepared higher education students the opportunity to develop the necessary mathematical skills to pursue their education and career goals. It is apparent from this study and other research on developmental mathematics programs in community colleges and universities that developmental programs not only create an opportunity for students, but can also create

barriers to students. Although developmental mathematics courses can act as a barrier, research has shown that community college students who complete the necessary coursework are as academically capable as their student counterparts who were not required to take developmental mathematics courses (Bahr, 2008). It is the necessity of developmental mathematics combined with the negative impacts reflected in the historical and current lack of success with developmental mathematics programs that has propelled the process of developmental mathematics program redesign.

Several methods of redesign for developmental mathematics programs that were discussed in this study have shown mixed results in increasing student success. The redesign of developmental mathematics programs are generally designed to improve student mathematics knowledge and create core foundation skills to allow for moving on to college-level mathematics, while at the same time improving student retention and completion of the required coursework. Redesign of developmental programs even extends beyond the typical changes to college curriculum and instruction, but to secondary schools where programs designed to help students avoid the need for developmental mathematics entirely are being implemented.

As stated by Bahr (2008), “comparatively few remedial math students remediate successfully, and those students who do remediate successfully are disproportionately those who require the least assistance (p. 445). This sample records that were evaluated in this study mirror this statement of Bahr (2008). Statistical analysis of the student sample data for students in developmental mathematics courses between Fall 2008 and Spring 2016 at Heartland Community College, indicated that students scoring higher on the ACT mathematics exam completed courses at higher rates than student with lower ACT mathematics exam scores.

Regardless of instruction being in a traditional face-to-face or computer-based course, poor course completion and degree attainment rates were noted.

Poor course completion and degree attainment rates for developmental mathematics were especially noted for black students. Although a specific cause for the poor performance by these students is not known, it appears as though social and cultural influences outside of school may have played a substantial role in the lack of success in developmental mathematics (Bahr, 2008; Booth et al., 2014, Tinto, 1993). Designing a developmental mathematics program that supports the typical underprepared community college student, who experiences significant influences on their education by factors outside of the higher education institution, is a difficult task. Considering the immense population of underprepared students who enroll in community colleges each semester in need of developmental mathematics, the continued pursuit of a developmental mathematics program design that helps remedy these influences and increases student course completion and degree attainment is a worthy pursuit.

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