# THE EFFECTS OF ACCELERATION IN DEVELOPMENTAL MATHEMATICS ON LOWEST-LEVEL PLACED STUDENTS AT UTAH VALLEY UNIVERSITY

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by

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## ABSTRACT

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In this dissertation, acceleration in developmental mathematics at Utah Valley University through compression of a 4-course sequence into a 2-course sequence was examined to determine the extent to which sequence length predicted student success outcomes, including completion of, pass/fail grades in, and re-enrollment into subsequent developmental mathematics courses for students with the lowest-level incoming placement exam scores. A two-year sample of students in the pre-reform 4-course sequence and a two-year sample of students in the post-reform 2-course sequence were analyzed using binary logistic regression, controlling for age, sex, race, and attempt number were conducted to examine completion of developmental mathematics courses and enrollment into subsequent developmental mathematics courses after passing the first course. Chi-squared tests of association were also conducted to examine the relationship between sequence length and whether the lowest-level placed students passed their first or second semester in developmental mathematics coursework.

The findings of this study suggested that the post-reform 2-course sequence may have a detrimental effect on student success outcomes in developmental mathematics courses for the lowest-level placed students, however broad confidence intervals prevented firm conclusions. Goodness of fit measures showed that the models created in this study do not account for a large portion of the variance in the student success outcomes, indicating that factors other than sequence length, such as Pell grant eligibility, first generation status, and other cognitive and affective characteristics would be better predictors of success. Reduced course sequences could be an effective option as part of a holistic developmental mathematics program that meets the various needs of its students. However, as an isolated change without consideration of varied ideal learning rates, a shortened sequence does not have a meaningful impact.

KEY WORDS: Utah Valley University, Developmental education, Developmental mathematics, Accelerated sequence, Developmental math program redesign, Logistic regression, Chi-squared, Passing rates, Completion rates, Re-enrollment rates, Sam Houston State University.

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# CHAPTER I

## Introduction

Higher education is continually changing, as efforts to improve student success while simultaneously reducing costs requires institutions to regularly reevaluate their programs. Currently, the field of higher education is inundated with reports and findings which create a crushing portrayal of dismal outcomes. In 2014, Complete College America reported that less than half of full-time students in public colleges graduated within four years (Complete College America, 2014). Among community colleges, whose missions are to provide education for transfer students as well as workforce development (Dougherty & Townsend, 2006), students who dropped out between 2004 and 2009 cost federal, state, and local governments as much as $3.85 billion (Schneider & Yin, 2011). As such bleak numbers reported by various, sometimes well-funded, organizations capture the attention of college administrators and legislators alike, it is not surprising that an overarching sense of urgency to address issues in higher education with great speed could take hold. Confronted with such bleak depictions of steep costs of a postsecondary degree combined with highly discouraging failure rates, despite flaws in the methodology of research behind these numbers, administrators, faculty, and staff of higher education institutions are driven to explore, research, and even experiment with education models that may improve student success.

The stakes are high for students whose entrance into the work force depends on the completion of a degree. In 2009, President Barack Obama (The White House Office of the Press Secretary) introduced the American Graduation Initiative, setting a goal for the United States to have the highest proportion of college graduates on the globe by

2020 as a major part of the overall effort to strengthen the nation's economy. Carnevale et al. (2010) predicted approximately two-thirds of all employment would require at least some college education from workers by 2018. Indeed, the need for a college education along with its associated costs have never been so high. However, issues in higher education are complex and multi-faceted with a web of integrated structures. Practitioners who work together for the benefit of students and to create opportunities for educational success combined with concerted efforts to improve student outcomes are a naturally constant feature of the higher education sector. However, the fervor surrounding these issues led to the birth of a movement to critically examine the contributors and obstacles to student success outcomes. This movement known as "the completion agenda" almost entirely focuses on timely graduation rates and creates concerns of a "serious quality of learning shortfall that threatens to get worse if we maintain an *exclusive* focus on completion and efficiency" (Humphreys, 2012, p. 3, emphasis in original).

Attrition is also a major issue among college students and, of those who do complete, only 5%-15.9% of Certificate or Associate's Degree earners and just 19%-36% of 4-year degree earners graduate on time (Carnevale et al., 2010). Although there are many other factors involved in the higher education success of students, many job market economists, statisticians, and some practitioners in higher education have targeted and blamed developmental education for complex issues such as retention, persistence, and completion (Complete College America, 2012; Martorell & McFarlin, 2011; Scott-Clayton & Rodriguez, 2012). The primary focus of developmental education is to serve underprepared college students and to help them reach their full academic potential. Students who enter college with low-level skills in reading, writing, and mathematics are given additional courses in which students can develop these necessary skills in students while also giving them the tools they need to be effective learners. Developmental programs for students not ready for college-level coursework are designed to provide "more structure, more feedback, and more support than they would have in conventional college courses" (Kulik & Kulik, 1991, p. 2). Programs may include coursework with specialized instruction to build the necessary skills for college success to compensate for a previous lack of preparation. They may also include counseling or advising to address non-cognitive issues that may be obstacles for students to reach their full potential. Well designed, comprehensive, and holistic developmental programs which include "individual tutoring, guidance, learning centers, study skills courses, and other services" are particularly well equipped to "recruit and support members of groups that were socially, economically, and educationally deprived" (Kulik & Kulik, 1991, p. 5). However, the completion agenda and somber reports of dreadful outcomes are used by many to create a view of developmental education programs, fashioned to help students, as an obstacle to student success at best, and an entity actively preventing student success at worst.

A major contributor to the sense of urgency to reduce, or even remove, the so-called obstacle of developmental education is a study of 57 Achieving the Dream colleges by Bailey et al. (2010). The authors stated that only one third of students placed into a developmental mathematics course and almost half of students placed into a developmental reading course completed their assigned developmental course sequences. They also found that the more courses in the sequence that students were assigned to take, the less likely they were complete college-level gateway courses because there were more opportunities to not enroll in the next course. However, their study does not account for differences in placement and assessment policies at individual institutions. It also examined outcomes for all students who placed into developmental education and not just students who attempted these courses, essentially holding developmental education administrators and faculty accountable for students whom they never had a chance to serve (Fong et al., 2015).

In another study by Scott-Clayton and Rodriguez (2015) of the effects of developmental education in college, the authors concluded that developmental education courses' primary function was to divert students away from graduation rather than develop necessary knowledge and skills in underprepared students and has been cited by many subsequent studies and articles to arraign developmental education (Bailey & Jaggars, 2016; Clotfelter et al., 2015; Hodara & Xu, 2016; Valentine et al., 2017). However, Scott-Clayton and Rodriguez fail to provide evidence that this "diversion" ultimately leads students away from college success rather than give students the time and assistance needed to build their academic skills, as developmental education is designed to do. The rhetoric of failure which permeates much of the current language used around developmental education programs should not detract from the overall societal purpose of developmental education nor the needs of the students which it serves.

While studying the demographics of developmental students in higher education, Boylan et al. (1994) found that developmental students have many commonalities to college students in general, meaning they are a diverse population and have varied needs. Similarly, the reasons for their lack of college readiness are wide in range and disparate in nature. These reasons range from delayed enrollment into college, to a misalignment of secondary and postsecondary education standards (Shelton & Brown, 2010). As a direct result of this diverse population with diverse needs, it is difficult to create a program that effectively serves every student and guides them toward graduation, but those who work in higher education institutions, along with legislators, are motivated to improve student success outcomes. But this motivation must be accompanied with careful wariness of umbrella statements framing ubiquitous complex issues of higher education as the failings of current developmental programs. Educators should be particularly wary of statements which encourage students and colleges alike to be resigned to the apparent dismal likelihood of college completion or to dismiss students with lower abilities and "adjust their investments sooner rather than later" (Scott-Clayton & Rodriguez, 2012, p. 5).

**Background**

The field of developmental education is particularly susceptible to criticism and regular policy changes because of the large numbers of students it serves and the low rates of successful outcomes. Approximately 70% of college enrolled students are referred to a developmental mathematics course and 34% are referred to a developmental English course (Biswas, 2007). These high rates, particularly in developmental mathematics, demonstrate the need for opportunities for students to improve their skills, not the failings of the very programs designed to help them. However, the best methods and policies to provide these opportunities can be elusive and difficult to refine, particularly in developmental mathematics.

***Developmental Mathematics***

Developmental mathematics programs at institutions of higher education often include a sequence of courses, beginning with basic arithmetic and continuing through intermediate algebra, in preparation for college algebra or another college-level mathematics course. Many programs also have student support services to assist students to be effective in their studies. The main factors that impact student placement is the time since their previous mathematics course as well as basic mathematical skills and abilities (Zientek et al., 2014). Additionally, factors that hinder student success within their developmental mathematics courses include not forming good study habits or work ethic in mathematics, receiving less encouragement from counselors and teachers, poor attendance, and time in between mathematics courses (Fike & Fike, 2008, 2012; Li et al., 2013; Zientek et al., 2014). Of concern for many are reported graduation rates of students placed into developmental mathematics courses. At 4-year institutions, 55.7% of students not placed into developmental mathematics graduate within six years, while only 35.1% of students placed into developmental mathematics graduate within six years (Complete College America, 2012). In response, sweeping reforms and redesigns to developmental mathematics programs are taking hold across the nation despite the complex nature of developmental programs and the mixed results of these redesigns (Bishop et al., 2018; Bragg et al., 2010; Lucas & McCormick, 2007) .

State policy also affects the way institutions design their developmental mathematics programs. Frustrated with the cost of these programs combined with the low retention and success rates, legislators put pressure on the schools to innovate in ways that might improve outcomes for students, but also reduce the strain on budgets (Biswas, 2007). As a result, further pressure is placed on institutions as they redesign their developmental mathematics programs by utilizing different models of acceleration and associated student support structures (Edgecombe, 2011; Hagedorn & Kuznetsova, 2016; Nodine et al., 2013).

Students who are placed into the lowest level course of developmental mathematics sequences are the most at risk for not graduating. These are students who need basic foundational mathematics skills, such as numerical operations and a working knowledge of integers. Despite having the greatest needs, not much is known about the weaker prepared students and what services may be most effective at helping them achieve success. Developmental mathematics courses provide support and structured learning environments for these students who may be unlikely to initially succeed in a college-level mathematics course (Boatman & Long, 2018). Hodara and Xu (2016) found that the cost of additional college courses along with the time added to obtaining a degree may mean that college is not the best option for these lowest-level placed students. They suggested that some of these students might be better off forgoing college altogether and joining the work force, gaining experience and wages. However, the social justice foundations of developmental education which maintain the potential of all students requires that institutions of higher education should work with these students and provide them with opportunities to succeed, regardless of ability level in order to truly make a positive difference in communities and society as a whole.

***Social Issues of Developmental Mathematics***

College mathematics requirements are designed to strengthen students' quantitative literacy to function in the work force and as citizens. However, these requirements can act as a barrier to achievement in college, adversely affecting students of color (Bahr, 2010b; Hodara & Xu, 2016; Martorell & McFarlin, 2011) and students in low socioeconomic brackets (Dougherty & Kienzl, 2006) because they are at risk for needing developmental mathematics classes, adding to the time and resources necessary to graduate. Nevertheless, there is a great need for quantitative literacy in the workforce. The likelihood of full-time employment is greatly influenced by quantitative literacy skills, especially for people of color. The cognitive skills that are taught in developmental mathematics courses are important factors in potential earnings (Murname et al., 1994, Rivera-Batiz, 1990). Quantitative literacy is also necessary for citizens of a data-rich society for information gathering and decision making. Developmental mathematics is a place to empower students with the skills necessary for participation in civic issues (Branson, 2019). The balance of the benefits of developmental mathematics and what some view as a hindrance to graduation causes much of the instability that is seen in the field.

**Statement of the Problem**

In response to the issues of high attrition rates in developmental mathematics combined with pressures from legislators, colleges across the country have endeavored to redesign their programs. State policies also affect the way these institutions design their developmental mathematics programs and colleges then innovate to improve student success while simultaneously reducing the strain on budgets. Many programs around the country have implemented reform by using acceleration models for developmental mathematics sequences. The efficacy literature surrounding these accelerated models showed some promising trend of higher student completion rates (Bragg et al., 2010; Edgecombe, Jaggars et al., 2013; Jaggars et al., 2015), however, other studies show only modest increases in success rates (Lucas & McCormick, 2007; Sheldon & Durdella, 2010), while still others show no increase in completion rates of reformed programs (Bishop et al., 2018).

The colleges implementing these accelerated programs are each utilizing models that are as unique as their respective colleges and the students in them. For example, some models include mandatory laboratory hours for the students while others provide occasional tutoring. Some models have student success courses to supplement the mathematics courses while others have intensive advising. No two programs are alike and understanding what leads to student success is paramount to any school considering a redesign of their developmental mathematics program. The use of different models results in varying degrees of success, leaving the relationship between the two ambiguous and uncertain.

More research must be done to study the resurgence of acceleration in developmental mathematics and its corresponding student success outcomes to truly uncover the characteristics or combinations of characteristics that contribute to a successful program. Institutions of higher education that have implemented some form of accelerated developmental mathematics program can benefit greatly from additional research and the further understanding of what leads to a successful developmental mathematics program. Furthermore, faculty and administrators who are carefully observing these programs while considering the efficacy of programs at their own institutions can also benefit from additional research. More research needs to be done to find the relationship between the structure of developmental mathematics programs combined with student support features and their corresponding student success outcomes. Very few studies about acceleration in developmental mathematics have focused on the students placed into the lowest-level courses (Boatman & Long, 2018; Martinez, 2018; Xu & Dadgar, 2018). Most studies examine students who were near the cut-off for college-level mathematics (Calcagno & Long, 2008; Martorell & McFarlin, 2011; Melguizo et al., 2011; Moss et al., 2014; Scott-Clayton & Rodriguez, 2012), but the students placed into the lowest-level courses have the most need for intervention. This study further informs the understanding of the relationship between the structure of developmental mathematics programs and the student success outcomes of these specific students.

Developmental mathematics programs and their current redesigns employ many different approaches to shorten the calendar time required for students to complete a developmental mathematics sequence to save resources and, ideally, increase the completion and graduation rates of these students. Types of developmental mathematics program redesigns include mainstreaming, co-requisite courses, compressed courses, and accelerated sequences. Mainstreaming involves the elimination of developmental mathematics courses, immediately placing students into college-level courses, often with additional support systems to help students catch up on any skills they need (Denley, 2016; Logue et al., 2016). Co-requisite courses also place students immediately into college-level mathematics courses but provide a second course to be taken simultaneously with structured learning for required interventions (Park et al., 2018). Compressed courses are semester-long courses that are reduced to a block class, or even intense four- to six-week seminars, but do not necessarily reduce the number of courses required in a developmental mathematics sequence (Guy et al., 2015; Sheldon & Durdella, 2010; Weisburst et al., 2017). Finally, accelerated models decrease the number of courses in a developmental mathematics sequence by eliminating overlapping and unnecessary concepts or objectives while increasing the pace of the remaining curriculum objectives (Hagedorn & Kuznetsova, 2016). This study focused on an accelerated model of developmental mathematics program reform, which decreased the number of classes required and the calendar time spent in below-college-level courses in efforts to reduce the number of students who drop out during their first year of college and increase GPA in developmental courses.

A major concern of these program reforms must be how they affect students of all mathematical ability levels. Increases in completion and graduation rates of students in these redesigned programs must be carefully measured with the success rates of individual students in these programs. Increases in GPA, retention, and completion rates among first-year developmental mathematic students in general may not reflect the reality that many students are experiencing (Cafarella, 2016b, 2016c). It is possible that these increases in student success outcomes are due to an improved program for students who are placed in higher levels of developmental mathematics courses or students on the margin of college-level mathematics courses, but simultaneously sacrificing the student success outcomes of the lowest-level placed students. This would defy the social justice underpinnings of developmental education and must be addressed to ensure that colleges are serving all their students and giving each student an opportunity for success. Therefore, in this trend of reform, it is essential that more be done to examine the outcomes of the lowest-level placed students.

**Scholarly and Educational Implications of the Study**

This study is an important academic contribution to the literature of developmental mathematics reform. The findings of this study further the understanding of what leads to the success of students in developmental mathematics and in their college careers. Scholarly research within the field of developmental education, and developmental mathematics is essential to the continued growth of and knowledge within the field and, as such, is essential to sustained student success. This study helps to fill the gap in the literature of developmental mathematics reform and program redesign models, particularly with accelerated models regarding students placed in the lowest-level courses. A greater understanding of what leads to student success among the lowest-level placed developmental mathematics students is essential to effectively serve high-risk student populations.

Additionally, this study is a meaningful contribution to the practice of educating developmental mathematics students as it can guide the faculty and administrators of other colleges in their decision of what kind of reforms, if any, they wish to implement in their own institution. Furthermore, this study adds to the resources that leaders of developmental mathematics programs can refer to as they work to increase student success. This study also could be an asset to developmental faculty who are redesigning their pedagogy in the classroom to better align with best practices in the field and with the structure and goals of their program. There are many administrators and faculty of developmental mathematics programs who are observing these redesign models and tracking the subsequent effects on student success. In this wave of reform, the multitude of options leave those who serve these underprepared students with the daunting prospect of considering which model might help to improve their own developmental mathematics program. Specifically, this study addressed the question of sequence length and how it contributes to or inhibits success for the lowest-level placed mathematics students.

**Purpose of the Study**

Many developmental mathematics programs have begun to employ acceleration as a model for increasing student success. These accelerated programs are designed to "hasten students' progression through freshman or general education courses, while still providing resources and support for a successful first year experience" (Lucas & McCormick, 2007, p. 37). The balance of increasing student completion rates without sacrificing necessary support is difficult to negotiate and must be conscientiously studied to ensure that the opportunity of higher education is available to the most vulnerable students. Thus, there is a continued need for research on the specific elements of accelerated programs, which are designed to expedite student completion, and their accompanying student success outcomes. The purpose of this study was to examine the extent to which the number of courses required in a developmental mathematics sequence effected student success outcomes for students with the lowest levels of standardized placement exam scores.

Measures of student success are difficult to determine as student success is difficult to define. However, some of the primary indices capturing student success are GPA and persistence through the first year of college (Acosta et al., 2016; Crisp &

Delgado, 2014; Silverman & Seidman, 2011). Therefore, this study defined success using GPA and student completion of first and second developmental mathematics courses. Researchers in the field have varied suggestions on how to increase student GPA and persistence in the first year of college, many of which currently involve the acceleration of developmental mathematics sequences. Mixed results in student success from studies of redesigned programs demonstrate that the efficacy of these accelerated programs is inconsistent and further study of what best predicts student success is greatly needed.

Specifically, this study looked at the Developmental Math department at Utah Valley University (UVU) and compared student success outcomes among the lowest-level placed students from the previous 4-course sequence and the new 2-course sequence. In the past, the Developmental Math department at UVU offered a 4-course sequence to students with the lowest placement scores. However, recent changes led to combining these four courses into a 2-course sequence. Through the elimination of redundancy and increasing the credit load of each course, faculty and administrators condensed these four courses, which were three to four credits each, into a 2-course sequence, which are four and five credits, respectively. This change greatly reduced the calendar time that students were required to spend in developmental mathematics courses and the number of exit-points where students could withdraw from the program or not enroll in the subsequent course.

This study distinguished between students who withdraw from a class and those who receive a failing grade by evaluating the likelihood of course completion. Students who do not pass a course because they withdrew may have very different needs from students who did not pass because they received a failing grade. These needs and how to developmental programs and instructors can address them is a valuable contribution to the field. The assumption that the length of the developmental mathematics course sequence has an impact on outcomes, particularly to lower the withdraw rate, was the driving force behind these changes and this study examined the changes in sequence length and its impact on the lowest-level placed students and their student success outcomes.

The 4-course sequence is considered problematic among many in the field of developmental education. Four semester-long classes can take two years or more for a student to successfully complete. For students placed in the lowest-level course, this can be a daunting requirement and may be discouraging for students. Additionally, this comes with many exit-points where even students who pass their current developmental mathematics course can choose to not enroll in the subsequent course. Bailey et al. (2010) found that 27% of students referred to developmental mathematics did not enroll in any developmental education course and 11% enrolled in a developmental mathematics course, but did not complete their sequence even though they never failed a course. This finding suggests that opportunities to not enroll in a course pose the greatest threat to student completion but could also indicate that students withdrew from a developmental course at some point. Bailey and his colleagues also found that 29% of students referred to developmental mathematics enrolled in and then withdrew or received a failing grade in a course in their sequence. However, they did not distinguish between students who withdrew and students who received a failing grade, which this study does, nor do they examine reasons for student departure from their prescribed sequence other than sequence length. UVU has its own mission and goals with a unique student population to serve. It is unknown if the 4-course sequence was a factor in some students' decision to depart the developmental mathematics sequence prior to completion. Notwithstanding, the administrators and faculty of the developmental mathematics program at UVU chose to reduce the number of exit-points within the developmental mathematics sequence by decreasing the required sequence length in an effort to increase persistence. This study examined the effectiveness of this redesign of the sequence.

The previous developmental mathematics sequence consisted of four courses beginning with Math Fundamentals (3 credits) and a curriculum of basic operations with decimals, fractions, and integers. The second class, Foundations for Algebra (4 credits) included mathematics concepts like those found in typical pre-algebra classes, such as roots, exponents, linear functions, and polynomial expressions. The third class, Introductory Algebra (4 credits), included systems of equations, rational expressions, complex numbers, and quadratic equations. The fourth and final class prior to enrolling in the college-level gateway course, often College Algebra, was Intermediate Algebra (4 credits), which included nonlinear equations, conic sections, and real-world applications of algebra. After the developmental mathematics courses were completed, students could enroll in their college-level gateway course.

The post-reform developmental mathematics sequence only includes two courses. The first post-reform course, Foundations for Algebra (4 credits), is a combination of the first two pre-reform courses and the second post-reform course, Integrated Beginning and Intermediate Algebra (5 credits), is a combination of the third and fourth pre-reform courses. All overlap in the curriculum was eliminated and other departments were consulted to determine which content objectives could be eliminated without depriving students on the knowledge and skills they would need for future classes, particularly classes which require completion of any assigned developmental mathematics courses as a prerequisite. The structure and pedagogical approach in the two post-reform courses also changed to include more adaptive teaching methods by "mak[ing] special effort to adjust curricular coverage and bring in special materials for special aptitude groups" (Kulik & Kulik, 1991, p. 12). Each of the two post-reform courses included extra in-class time each week to bring in embedded peer tutors, who worked as tutors in the campus Math Lab. The Foundations for Algebra course (4 credits), which would traditionally include 200 minutes of in-class time per week, was scheduled for 240 minutes per week, while the Integrated Beginning and Intermediate Algebra course (5 credits), which would traditionally have 250 minutes of in-class time per week, was scheduled for 300 minutes per week.

Alongside the instructors, embedded tutors would work with students in smaller groups and even one-one-one with students during the extra time as a way to implement instructional methods which consider numerous ways of learning and provided a more personalized learning experience. This structured time, beyond the traditionally time spend in class, was designed to accommodate students of differing mathematical aptitude and provide adaptive teaching environments by "alter[ing] instructional conditions for individual students" and "tak[ing] differences in learning rate into account" (Kulik & Kulik, 1991, p. 10). However, the embedded tutors and extra time were not uniformly adapted in all sections of the post-reform courses. Instructors had to individually request embedded tutors for each section they taught instead of a universal system to automatically assign embedded tutors to section of post-reform courses. Many instructors chose to use some of all of the extra 40-50 minutes of in-class time each week as an extension of traditional instruction time, or even to dismiss official class early, recommending to students that they use that time to seek out their own personalized instruction or tutoring.

**Research Questions**

In the Developmental Math department at Utah Valley University, the course sequence consisted of four courses that students test into based on placement test scores. Once these courses were completed, students could then move on to their gateway course. However, recent changes have been made as part of an effort to increase student success outcomes. The sequence now consists of two courses that must be completed prior to the gateway course. In this study, the different sequence lengths in which students have been enrolled in the pre-reform and post-reform developmental mathematics program were utilized to examine the impact of sequence length on a range of student success outcomes.

**Research Question 1 (RQ1).** To what extent does sequence length predict the completion of the first developmental mathematics course for the lowest-level placed students, controlling for number of attempts, sex, race, and age?

**Research Question 2 (RQ2).** To what extent does sequence length predict grades in the first developmental mathematics course for the lowest-level placed students, controlling for number of attempts, sex, race, and age?

**Research Question 3 (RQ3).** To what extent does sequence length predict the completion of the second developmental mathematics course, controlling for number of attempts, sex, race, and age, for the lowest-level placed students?

**Research Question 4 (RQ4).** To what extent does sequence length predict grades in the second developmental mathematics course completion, controlling for number of attempts, sex, race, and age, for the lowest-level placed students?

## Definition of Terms

The following terms are defined for the purpose of this study.

Developmental mathematics: Courses offered at a college which are designed to prepare students for college-level mathematics coursework.

Lowest-level placed students: Students whose placement scores assign them to a developmental mathematics course that is four levels below their college-level gateway course in the pre-reform sequence, or two levels below their college-level gateway course in the post-reform sequence.

Pre-reform sequence: The traditional or previous developmental mathematics sequence of four course levels.

Post-reform sequence: The reformed developmental mathematics sequence of two course levels.

Course completion: The receival of a grade in a course, i.e. a grade of A, A-, B+, B, B-, C+, C, C-, D+, D, D-, or E; not a grade of Incomplete (I), Withdrawal (W), or Unofficial Withdrawal (UW).

## Assumptions, Limitations, and Delimitations

This study of the efficacy of acceleration in developmental mathematics was based on several assumptions. It was assumed that the instructors for each of the developmental mathematics courses were qualified, experienced, and effective teachers who were capable of guiding students to the fulfillment of their potential. It was also assumed that all students who enter the developmental mathematics program were capable of learning the required skills to successfully complete these courses. Additionally, this study, as with all research, had several limitations. First, the placement process at this university utilized the results of an exam, the ACT, ACCUPLACER, or ALEKS, as the sole resource to determine placement into developmental mathematics courses. College entrance placement exams have been criticized for their lack accurately predicting student success in different levels of developmental education, (Ngo & Kwon, 2014; Scott-Clayton, 2012; Scott-Clayton et al., 2014). However, placement exams are designed to measure mathematical skill at a given point in time, a function at which they are reasonably accurate (Saxon & Morante, 2014, 2015). Holistic advising and affective skills measures would contribute to accurate student placement and the lack of these considerations created a limitation on this study.

Second, the student success outcomes of developmental mathematics students at one open enrollment university and may not be generalizable to community colleges or universities with different demographics. There are also a multitude of student support structures and resources, such as the campus tutoring, mathematics mentors, and learning strategists which could also influence student success outcomes. While the purpose of this study is to examine the effect of sequence length on student success outcomes, it is not the purpose of this study to examine these various student supports that are in place, which could influence the student success outcomes. These limitations had potential to lead to validity threats, such as measurement validity, and multiple treatment effects. Internal and external validity threats are discussed further in Chapter 3.

Additionally, the developmental mathematics program redesign at this institution had only been in place for approximately two years. The long-term effects of the program cannot be measured at this point but should be studied as the program continues to ensure the best outcomes for the students. The limited amount of post-redesign data also limited this study's ability to measure completion rates past two years. The three-year completion rate for students in the post-reform sequence may be a better measurement of the efficacy of the shortened sequence and should be the focus of a future study.

The delimitations of this study involve the specific group of students that were to be evaluated. This study focused on the lowest-level placed students and the extent to which the developmental mathematics course sequence length predicted certain student success outcomes. Mid-level and high-level placed students were not studied. These students should be included in a future study as they may have different outcomes than their lowest-level placed peers, however, it is the purpose of this study to illuminate the effects of acceleration in developmental mathematics on the least prepared students, an important subgroup of the students that these programs serve.

**Conclusion**

Across the nation, the trend of acceleration in developmental mathematics is taking hold as many institutions try to increase student success outcomes in the face of decreasing budgets. State legislative policies have forced many institutions to initiate reforms without much evidence for its efficacy, especially among the lowest-level placed students. Additionally, each developmental mathematics program reform employs different strategies and features unique to their institution and students. Efforts to improve developmental education, particularly developmental mathematics are commendable and should be encouraged at student, faculty, institution, and state level. The issue of high attrition rates and low passing and completion rates among these high-risk students is worthy of examination and must be addressed. Lowest-level placed students are at particular high risk of these negative outcomes and may require specific interventions that tackle the challenges experienced by this group. Developmental educators must carefully consider any reforms that may impact each level of students who participate in their programs to ensure opportunity and support for all their students. The results of this study inform the developmental mathematics community of the effects of one model of redesign on their most vulnerable student populations.

# CHAPTER II

## Review of the Literature

Developmental mathematics programs consistently demonstrate the need for improvement in student success outcomes. Recent changes to programs adopting accelerated models have shown promise, however, there is still more research needed on the topic. This review of the literature begins with a discussion on the efficacy of developmental education in general and then focuses further on developmental mathematics in particular, along with best pedagogical practices and their role in student learning. Definitions and example models of developmental mathematics programs are discussed with a focus on studies which analyze the issue of sequence length and the program redesigns that address calendar time to completion of a developmental mathematics sequence. The resurgence of accelerating developmental programs is still relatively new; however, there is a need to continually examine all the current results and student outcomes that various institutions are producing. As a practice, these accelerated programs are becoming more prevalent and efforts to understand the implications of this practice are necessary for the improvement of all aspects of developmental mathematics. However, the current knowledge of how these program redesigns affect lowest-level placed students and their pathways through college is lacking and must be further studied to ensure the welfare of this important population of developmental students.

Additionally, this review discusses demographics of developmental students, particularly students entering the developmental mathematics programs in the lowest-level courses. Issues of first-year retention are discussed along with the conceptual framework of this study. Finally, the literature is synthesized and discussed in a manner that allows patterns and gaps in the research to become clearer. The results of various program redesigns are provided to demonstrate the differences in outcomes among the many diverse models. Programs that utilize accelerated models along with multiple student support structures, consistently show better results in student success (Edgecombe, Jaggars, et al., 2013; Scrivener et al., 2015; Sommo & Ratledge, 2016) than programs that accelerate the developmental mathematics process without any additional student support services, which show far lower gains in student success rates (Bishop et al., 2018; Hodara & Jaggars, 2014; Lucas & McCormick, 2007). Further research is needed to identify the effects of shortened course sequences and the extent to which this form of acceleration should be involved in efforts to improve outcomes for developmental mathematics students and the key elements and combinations of support structures that lead to overall student success, particularly the lowest-level placed students who require the most intervention to achieve their goals.

**Efficacy of Developmental Education**

Developmental education is distinguished from remedial education by a more holistic approach to student success, moving beyond basic content skills to additional supports available to bolster students' ability to thrive throughout their college education. Open door policies of community colleges and some 4-year institutions which continue to make college opportunities available to more students have created a public and academic "flash point of ideologies" held by many of the purpose of developmental education and higher education as a whole (Shaw, 1997, p. 285). These ideological debates are rooted in beliefs in the responsibility of higher education to educate the most vulnerable citizens. In a qualitative study of overall approaches to developmental education and the programs implemented by different community colleges, Shaw (1997) found that these ideologies were a determining factor in which approach was taken. Student-centered ideologies led to developmental programs that promoted faith in student ability, decreased stigmas associated with developmental education, and recognized faults within the entire system of education that led to student placement into these programs. Other ideologies that placed blame with students and contributed their lack of success to personal shortcomings led to developmental programs that promoted a gatekeeper mentality where only students deemed to have merit can continue to college success. Shaw argued that these underlying ideologies were responsible for the overall approach to developmental education each institution employed and, therefore, affected student success outcomes (Shaw, 1997).

Kolajo (2004) studied graduates of a community college and found that students who took one developmental course did not have statistically significant differences in GPA when compared with students who did not take any developmental courses. However, students who took more than one developmental course had much lower overall GPAs and took more time to graduate than students who did not take any developmental courses. Kolajo acknowledged that developmental education must be included in any open admission institution, but noted that some accountability measures might disadvantage these institutions due to the high numbers of students who require developmental courses and who attend school part-time (Kolajo, 2004). The efficacy of developmental education, therefore, is difficult to measure, particularly when comparing different institutions, each which have different ideologies and aspects of developmental programs.

Despite the challenges to examining developmental education impacts on student success outcomes, there have been many studies that have attempted to describe the paths of developmental education students. In their study of 57 *Achieving the Dream* colleges, Bailey et al. (2010), as discussed in Chapter 1, found that of those students who were referred to developmental education courses, 27% did not enroll in any developmental education course within three years. Additionally, among students referred to developmental reading coursework, 46% completed their entire sequence, and only 33% of students referred to developmental mathematics coursework completed their sequence. Finally, only 37% and 20% of students referred to developmental reading and developmental mathematics, respectively, completed a college-level gatekeeper course within three years. This study also found that many students drop-out at the exit points between courses where the opportunity to not enroll in the subsequent course exists (Bailey et al., 2010). However, their study did not distinguish between students who withdrew during a course or students who failed their developmental courses, an important difference.

Other studies have also examined milestones in developmental and college-level courses as students progress through college courses. One important milestone that is often measured is retention. If students are dropping out during a course or at these exit-points, the rates at which this happens is an important indicator; however, the findings have been mixed. In their study of college students in Ohio, Bettinger and Long (2005b) found that developmental education had positive effects on retention. Their study showed that developmental education courses decreased the likelihood that a student would drop out by almost ten percentage points, compared to similar students who were not enrolled in developmental courses. Another study discovered that students requiring developmental education courses were more likely to persist to their second year of college, albeit only slightly (2% to 3.8% more likely; Calcagno & Long, 2008). Brower et al. (2013) noted that enrollment into a developmental course in the first semester of college increased likelihood of persistence to the second semester and the second year, but did not predict persistence to the third year. However, in a study comparing developmental and non-developmental students at 2-year institutions, Crisp and Delgado (2014) found that there was no statistically significant relationship between developmental status and student persistence to their second year of college.

The next milestone for developmental students is the completion of their assigned developmental sequence. Bettinger and Long (2005b), determined that 71% of Ohio students who had taken the ACT completed their developmental sequences while only 56% of non-ACT takers completed their sequence. Following the completion of their developmental sequences, students must then enroll in and then pass their college-level gateway courses. Bailey et al. (2010) found that only two-thirds of students who had completed their developmental sequence actually enrolled in the college-level gateway course and of those who did enroll, only three-fourths passed their college-level gateway course. However, Calcagno and Long (2008) discovered that enrollment into developmental education courses had little to no effect on the likelihood of passing the college-level course. Additionally, in a meta-analysis of regression discontinuity studies, Valentine et al. (2017) observed that students placed into developmental courses were eight percentage points less likely to pass their college-level course.

Finally, the relationship between developmental education and the college milestone of diploma, certificate, transfer to a 4-year institution, or attainment of a degree has long been examined. Bettinger and Long (2005a) found that developmental students were more likely to earn a bachelor's degree than their non-developmental peers. Attewell et al. (2006), in their study of the National Educational Longitudinal Study data, detected an increased likelihood of graduation among developmental students in 2-year colleges, but not in 4-year colleges. Calcagno and Long (2008) concluded that developmental education had no effect on certificate attainment, transfer, or associate degree completion and, similarly, Martorell and McFarlin (2011) saw no evidence that developmental courses affected degree attainment after four, five, or six years. However, Crisp and Delgado (2014) observed a statistically significant negative relationship between developmental coursework and transferring from a 2-year to a 4-year college. Finally, Valentine et al. (2017) ascertained that developmental students were less likely to earn a degree or certificate, although only by 1.5 percentage points.

To state that the results of studies on college milestones of developmental students is mixed is an understatement. Developmental education as a whole is a complex field and developmental students are characteristically different from non-developmental students (Crisp & Delgado, 2014). Additionally, developmental students are different from each other in different states, schools, and programs (Calcagno & Long, 2008). Criticisms of developmental education in its entirety are based on the supposed negative effects it has on student success outcomes and milestone achievements as some have reported (Bailey et al., 2010; Martorell & McFarlin, 2011; Scott-Clayton & Rodriguez, 2012). However, the literature showed very mixed results overall from positive to negative effects of developmental education and even null effects, making these effects difficult to define and to measure with any real accuracy. This is particularly evident in open admissions institutions. Attewell et al. (2006) stated:

> Ironically, when colleges require that their students demonstrate proficiency in basic skills by passing remedial courses, they are criticized for wasting the time of the students who fail to overcome these hurdles. At the same time, the provision of remedial courses is perceived by the public as indicating a lack of standards rather than as a mechanism for setting a basic skills standard. (p. 916)

In a qualitative study of student perceptions of developmental education, Koch et al. (2012) determined that students thought of developmental courses as beneficial to their growing skill sets and perceived value in their time spent in these courses. Collins (2010) suggested that the conflicting perspectives on the effects of developmental education stem from a lack of true experimental designs in the research and the absence of links between specific aspects of interventions and specific outcomes. Moreover, interventions or programs with multiple components can be impossible to study and find true causality of the outcomes, particularly among the many studies that implement a regression discontinuity design where “the risk is finding that developmental education does not work when, in individual instances, there may be strategies, programs, and practices that actually do work” (Collins, 2010, p. 6). This study specifically examined a developmental mathematics program with the exclusion of reading, writing, or English developmental courses. Therefore, the literature examining specific developmental mathematics programs and student success outcomes is discussed below.

***Efficacy of Developmental Mathematics***

Developmental mathematics is especially under scrutiny by researchers, college administrators, and state legislators. Additionally, more students are placed into developmental mathematics courses than other subject areas (Attewell et al., 2006; Bailey et al., 2010; Crisp & Delgado, 2014). However, just as in developmental education, the results of studies on the effects of developmental mathematics on various student outcomes are mixed.

Bahr (2008) conducted a study of first-time college students in the California Community College system and of the effects of successful completion of a developmental mathematics program. He examined over 85,000 community college students, sorting them into groups who initially enrolled in a college-level or remedial mathematics class. Bahr analyzed the relationship between initial mathematics enrollment with outcomes of certificate, degree, or transfer to a 4-year institution, controlling for college-level and student-level variables. Remedial students who went on to complete a college-level mathematics course had 15% greater odds of transferring to a 4-year institution with a credential already earned than students who began in and successfully completed a college-level mathematics course. However, this was the only statistically significant difference found between these two groups. In every other outcome, students who completed a college-level mathematics course "experience outcomes that are nearly identical to one another," regardless of whether they initially began in remedial or college-level mathematics (p. 435). Bahr noted that the similarities in outcomes of these two groups demonstrates the ability for developmental mathematics programs to successfully bring students to college-level mathematics readiness.

However, another finding of this study showed that many students who began in remedial mathematics courses, fared much worse, with 75.4% of them not going on to successfully complete a college-level mathematics course (Bahr, 2008). All students who successfully completed a college-level mathematics course had approximately a 65% chance of transferring to a 4-year institution, while students who began in remedial mathematics, but did not successfully complete a college-level mathematics course had only a 10% chance of transferring with an 83% chance of neither transferring or completing any credential. The very negative outcomes for these students show the need for more research on what helps students in need of mathematical ability assistance to be successful in their mathematics courses.

Bahr (2008) also noted that his findings do not deal with the effects of developmental mathematics coursework, but rather the effects of successfully completing developmental mathematics coursework and, therefore, cannot be used to show detrimental effects of developmental mathematics for any students. Indeed, Bahr stated that researchers who wish to examine the effects of developmental mathematics coursework “face a quagmire of problems associated with controlling confounding background characteristics of students” (p. 445).

Waycaster (2011) compared students at a Virginia community college who had successfully completed their assigned developmental mathematics sequence with students who placed directly into college-level mathematics courses. Results showed that 77% of developmental mathematics students passed their first college-level mathematics course compared to 75% of non-developmental mathematics students. A 2-proportion $z$-test resulted in a $p$ value of 0.68, showed no statistically significant difference between pass rates of developmental and non-developmental students (Waycaster, 2011). Abraham et al. (2014) studied first-time-in-college students across 70 community colleges in Texas from 2003 to 2008 and saw that the percentage of incoming students who required developmental mathematics coursework had remained static (40.63% in 2003, 41.07% in 2008; Abraham et al., 2014). The authors suggested that gaps in mathematical knowledge between secondary and post-secondary schools should be addressed through K-12 reform strategies. Additionally, they ascertained that the percentage of students placed into developmental mathematics coursework who then passed a college-level mathematics course within three years (5.44% in 2003, 5.57% in 2008; Abraham et al., 2014) had no statistically significant change in this time frame as well. However, the authors also report that first-time-in-college students who placed directly into college-level mathematics classes had a successful completion rate of 8.54%, demonstrating that all students could benefit from increased support in secondary education (Abraham et al., 2014).

In a study of six community colleges and 100,000 students, Scott-Clayton and Rodriguez (2012) found that 17% of students assigned to developmental coursework had not enrolled in college within three years. Additionally, after three years, 64% had dropped out, or discontinued enrollment without attaining a degree. However, the results of their regression discontinuity design study showed that assignment to developmental coursework in mathematics may delay enrollment but did not affect eventual enrollment. The researchers also identified no effects of developmental mathematics assignment on transfer or degree completion rates, dropout rates, or scores on a standardized exit exam score, although they did find that assignment to developmental mathematics leads to a

5% drop in the likelihood of passing a college-level mathematics course within three years (Scott-Clayton & Rodriguez, 2012). Scott-Clayton and Rodriguez also separated students by their risk-level of dropping out of college and concluded that assignment to developmental mathematics resulted in an almost 9% drop in the likelihood of passing college-level mathematics, but that for students with a high-risk of dropping out, there was just above a 3% drop in the likelihood of passing college-level mathematics, concluding that developmental mathematics may be less harmful to students at high-risk. Based on the findings that "assignment to remediation does not sufficiently develop students' skills in order to improve their chances of college-level success" (p. 41), the authors concluded that the primary function developmental education is to divert students away from college-level coursework, however they did note that they cannot say whether students learning was improved as a result of developmental coursework. Similarly, Clotfelter et al. (2015), using OLS regression, demonstrated that, among North Carolina community college students who enrolled between 2001 and 2009, students enrolled in any developmental mathematics course were 6.9% less likely to pass a college-level mathematics course, with students placed into the lowest-level developmental mathematics course 10.8% less likely to pass a college-level mathematics course. These authors similarly concluded that developmental mathematics mainly served to divert students away from college-level courses.

### ***Regression Discontinuity Research Design***

Of interest here is the number of researchers who relied on a regression discontinuity design to examine the effects of developmental mathematics on student success outcomes. Regression discontinuity is a quasi-experimental design that examines outcomes for students who place just below and just above the cut-off for developmental mathematics placement (Melguizo et al., 2011; Moss et al., 2014). The reasoning behind this method is that because these students around the cut-off have extremely similar placement exam scores, they can be considered statistically equivalent (Bailey et al., 2013). Therefore, measuring the differences in outcomes between these two groups can point to the effects of developmental mathematics. Many of the studies discussed above utilized a regression discontinuity design (Calcagno & Long, 2008; Martorell & McFarlin, 2011; Scott-Clayton & Rodriguez, 2012) and the researchers begin with the assumption that, for students near the cut-off, participation in developmental education should result in student success outcomes that exceed non-developmental students (Bailey et al., 2013; Goudas & Boylan, 2012). However, there is much debate over whether this is an appropriate assumption (Bailey et al., 2013; Goudas & Boylan, 2012; Goudas & Boylan, 2013). Goudas and Boylan (2013) stated that this assumption is not congruent with the purpose of developmental mathematics and that a student's "participation in… remedial college courses does not ensure a greater success rate at the middle or end of a gatekeeper course; this is because the new material presented at those time is new for everyone, former remedial students or not" (p. 29).

Nevertheless, the findings of studies that use a regression discontinuity research designed to examine the effects of developmental mathematics, once again, have mixed results (Calcagno & Long, 2008; Lesik, 2007; Martorell & McFarlin, 2011; Melguizo et al., 2011; Moss et al., 2014; Scott-Clayton & Rodriguez, 2012). In a regression discontinuity design research study of freshmen at a 4-year institution, Lesik (2007) found that 88.7% of developmental mathematics students were estimated to still be enrolled at the university after the first year while 62.7% of non-developmental mathematics students were estimated to be enrolled after the first year. In other words, participation in developmental mathematics coursework statistically significantly reduced the risk of dropout for first-time freshmen.

Additionally, in a study of students from a large community college, Moss et al. (2014) conducted a regression discontinuity design research study and discovered that placement into developmental mathematics improved the grades in a college-level mathematics course. Furthermore, Melguizo et al. (2016) also utilized a regression discontinuity design in their study of over 16,000 community college students. They uncovered evidence that placement into developmental mathematics decreased the likelihood of passing a college-level course, though these effects became insignificant after enough time passed and they suggested increased research on placement strategies (Melguizo et al., 2016, p. 180).

In addition to the mixed results of these regression discontinuity designs, the results cannot be generalized to all developmental mathematics students. The results are based on students who place at or near the cut-off of needing developmental coursework at all and can only be generalized to this smaller group and not to students who place into the lowest-level developmental mathematics course. This could suggest that "some community colleges might be doing a better job in the provision of the basic skills courses that are just below the college-level courses than the courses that are the high school prerequisites" (Melguizo et al., 2011, p. 180).

***Predictors of Success and Pedagogy in Developmental Mathematics***

The literature examining the effects of developmental mathematics showed mixed and even contradictory results, leading to literature on possible insights of what predicts success for these students. Fike and Fike (2012) compared students who placed immediately into college-level mathematics, students who enrolled in a developmental mathematics, and students who were placed into developmental mathematics, but delayed their enrollment for at least the first semester. Among these groups, students who deferred their enrollment into developmental mathematics had the poorest outcomes in retention and GPA. However, they also found that students who enrolled into their assigned developmental mathematics course, but failed to pass, experienced even worse retention rates and GPA (Fike & Fike, 2012). This suggests that immediate enrollment for any student placed into developmental mathematics is beneficial. The most powerful predictors of positive course behavior, success in these courses, and college-level courses are mathematical readiness (Li et al., 2013) and student GPA (Acosta et al., 2016).

In an effort to improve outcomes for developmental mathematics students at a particular open enrollment 4-year university, placement exam score cut-offs were increased, thereby requiring more mathematical ability for each placement level in the developmental mathematics sequence (Jacobson, 2006). However, despite higher enrollments and increased retention of students in developmental mathematics courses, they were less likely to complete their developmental mathematics sequence or succeed in a college-level mathematics course than students in the previous placement policy (Jacobson, 2006). The creation of an effective developmental mathematics program is a difficult balance and "the challenge is to engineer systems that could optimize both course success and program completion" (Jacobson, 2006, p. 157).

In a qualitative study surveying students who were successful in their developmental mathematics courses, Howard and Whitaker (2011) discovered that increases in student motivation and improved learning strategies accounted for students' success. Successful students reported increases in motivation due to monetary cost of failure/loss of tuition and contextualized understanding of mathematics. Additionally, students recounted strategies such as class attendance, asking questions, completion of homework, and utilizing available tutoring resources (Howard & Whitaker, 2011). The authors suggested practices that increase student engagement in the classroom, that contextualize the mathematical concepts in the real world, and that help students identify any negative "turning points" in their mathematical history that may have led to their placement into developmental mathematics, can increase the number of successful students in these courses (Howard & Whitaker, 2011).

Teaching techniques employed in the classroom may also benefit developmental mathematics students. Developmental mathematics students required additional assistance to bring their quantitative skills up to the point of college-readiness, and if high school mathematics courses were unable to accomplish this task, college classes taught with the same approach are unlikely to work a second time (Stigler et al., 2010). Zimmerman et al. (2011) studied an intervention in a technical college developmental mathematics classroom where students were taught self-regulated learning techniques such as instructor modeling, self-reflection opportunities, and rewards for attempts at learning. Researchers revealed that 68% of students in the self-regulated learning classrooms passed their developmental mathematics course, compared to 49% of students in a traditional classroom and students in the self-regulated learning classrooms surpassed students in traditional classrooms on passing a standardized posttest, 64% and 39%, respectively. Furthermore, the researchers determined that students in the self-regulated learning classrooms passed the college-level mathematics course, 76%, compared to 62% of students in traditional developmental mathematics classes (Zimmerman et al., 2011). These results indicated that changes to pedagogy in the developmental mathematics classroom can benefit students who are already at a disadvantage.

In many developmental mathematics courses, instruction is often found to be similarly ineffective across the board (Grubb, 2010). In a qualitative study of 13 California community colleges, Grubb (2010) observed that what he calls "remedial pedagogy" (p. 8), which is repeated decontextualized drill and practice of subskills, was the dominating instructional approach. The author advocated for pedagogical innovation through administrative focus on instruction, professional development, effective leadership, and an individual and contextualized approach to teaching and learning (Grubb, 2010). Many other researchers also observed the repeated practice of drilling students on routine procedures in developmental mathematics classrooms and an emphasis on arriving at the correct answer over a true understanding of the quantitative concepts involved (Cox, 2015; Quarles & Davis, 2017; Stigler et al., 2010). The "almost exclusive focus on teaching mathematics as a large number of procedures that must be remembered" is ineffective for student learning "[b]ecause the procedures were never connected with conceptual understanding of fundamental mathematics concepts" and students "have little to fall back on when the procedures fade" (Stigler et al., 2010, p. 15).

A pedagogy that is “premised on developing a multi-strand conception of mathematical proficiency” (Cox, 2015, p. 283) may have a more beneficial effect on student success outcomes than the structure of developmental mathematics programs (Quarles & Davis, 2017).

***Sequence Length***

Recently, research on the efficacy of developmental mathematics programs has put emphasis on developmental mathematics course sequence lengths that students are required to complete prior to enrolling in college-level mathematics courses. As discussed previously, Bailey et al. (2010) showed that 19% of incoming students were referred to developmental mathematics sequences that included three or more courses. They also discovered a negative relationship between the number of courses in a developmental mathematics sequence and the likelihood of successfully completing that sequence or passing a college-level mathematics course (Bailey et al., 2010). In their study tracking students’ progression through developmental and college-level mathematics courses at the largest community college district in California, Fong et al. (2015) used a step-wise logistic regression model to analyze the predictive nature of various factors on student success, including placement into one of the four courses in a developmental mathematics sequence. The researchers brought to light that many students do not progress due to failure in a developmental mathematics course or due to not enrolling in the subsequence course. However, they also found that students who placed into and passed the lowest-level developmental mathematics course were more likely to pass the subsequent developmental mathematics course than those who were initially placed into the higher-level course (Fong et al., 2015).

Melguizo et al. (2016) utilized a regression discontinuity design to examine the effects, not just of placement into developmental mathematics compared to college-level courses, but also of placement into each level of developmental mathematics compared to the subsequent developmental mathematics course. They discovered that the lowest-level placed students have worse student success outcomes than students who were placed into the subsequent higher-level developmental mathematics course, indicating that longer sequences have a negative effect (Melguizo et al., 2016). Hodara and Xu (2016) examined the effects of the number of developmental credits accumulated on the probability of employment and wage earnings for community college students in North Carolina and Virginia. They determined that each developmental mathematics credit earned decreased earnings each quarter by $18- $50, resulting in an average decrease of $54-$150 per developmental mathematics course (Hodara & Xu, 2016). However, developmental mathematics courses do not appear to impact wages for students who attained a credential through their schooling. Additionally, the model of this study did not directly address the issue of "students who earn more credits, especially more credits through developmental education courses, inherently follow a different wage growth trajectory than students who earn fewer credits" (Hodara & Xu, 2016, p. 797). Finally, developmental mathematics credits earned is not equivalent to developmental mathematics course sequence length, as many programs have varying credit loads for their developmental mathematics courses.

A unique study of four large community colleges in California where the elementary algebra developmental mathematics course was offered in two formats: a traditional one-semester course and an extended 2-semester course, had notable results.

Those placed into the extended course had lower placement scores and it was believed that more time to learn the concepts would increase success for these students. Kosiewicz et al. (2016) found that 89% of students who placed into the one-semester format actually enrolled into their first prescribed course while 71% of students who placed into the 2-semester format enrolled in their first prescribed course. Out of the students who originally placed into the one-semester format of elementary algebra, 30% of them enrolled into their gatekeeper mathematics course while 13% of students who originally placed into the 2-semester format enrolled into their gatekeeper mathematics course. Also, the students in the extended course format were 8-10% less likely to get a B grade or better in their gatekeeper mathematics course and about 20% less likely to get a C grade or better than those in the one-semester course (Kosiewicz et al., 2016). In the developmental mathematics program of these community colleges, extended time for lowest-level placed students to complete their elementary algebra course had the opposite of the intended effect. In other words, an extended sequence caused student performance to decline instead of increase.

A final study of the effects of developmental mathematics sequence length had the unique comparison of different colleges within a single community college system, each with their own sequence length in developmental mathematics. Hodara and Jaggars (2014) conducted a study to assess the effects of the shorter sequence length on developmental mathematics student outcomes. Data were collected from CUNY's Office of Institutional Research, including demographic information, from fall 2004 through fall 2007. The researchers studied the effects of sequence length on 3-year completion rates, grades in the developmental courses, and pass rates of the students in college-level courses. The researchers saw very small increases in success rates among the students taking shorter sequence programs. Students who took shorter sequence length programs were 3.5% more likely to enroll in college-level mathematics than students in the longer sequences. They were also 3% more likely to pass their college-level mathematics course. These gains were minimal and do not show great advantages of the shorter sequence. The researchers also concluded that those in the shorter sequence were only 1% more likely to earn an associate degree within three years when compared to those in the longer sequences (Hodara & Jaggars, 2014). At the time of this study, the CUNY system was a unique system because the only differences in the various programs were the sequence lengths. The researchers stated that "experimentation with acceleration through shorter sequences is a good starting point in order to improve access to college-level course-work and potentially students' overall college success" but acknowledged that the positive effects of a shortened sequence were "only mild in size" (Hodara & Jaggars, 2014, p. 271). This suggests that the adjustment of sequence length alone may not substantially improve student outcomes.

**Definitions and Models of Redesign**

Accelerated programs of developmental mathematics are becoming more common on college campuses. These models of reform, in response to high attrition rates and low success outcomes for students (Bailey et al., 2010), are quite diverse; however, the most common models include some form of restructuring of the courses in the program. The purpose of these accelerated models is to reduce the amount of time that it takes for students to complete the developmental mathematics program and move on to college-level mathematics. It is necessary to note that many schools that undergo a restructuring of their developmental mathematics program also take into consideration multiple factors that could affect their students' success. Additionally, many programs supplement their courses with additional structures, such as tutoring, student success courses, and additional advising to help their students confront and overcome obstacles students typically face, whether cognitive or affective. In what follows, definitions and examples of each model of reform is discussed and the impact of these redesigns on various student success outcomes is examined.

### *Mainstreaming and Corequisite Models*

Mainstreaming and corequisite models of redesign in developmental mathematics are similar in foundation by placing students directly into a college-level mathematics course upon initial enrollment. A true mainstreaming model involves a complete elimination of developmental mathematics courses (Edgecombe, 2011), but with additional support structures such as at Austin Peay State University where some sections of college-level mathematics were linked to tutoring sessions for students who needed extra assistance (Boatman, 2012). Corequisite models pair sections of college-level mathematics courses with developmental mathematics courses, requiring students to enroll in both courses simultaneously (Edgecombe, 2011). This allows students to engage in college-level mathematics while receiving just-in-time teaching for skills they may lack (Jones, 2015). Some states have implemented corequisite instruction through legislation, such as Tennessee where community college students are required to co-enroll in college-level mathematics and an additional support course (Denley, 2016); such as Texas where students are required to enroll in college-level and developmental mathematics simultaneously (Texas H.B.2223, 2017); or such as Florida, where students are given the option of mainstreaming or corequisite instruction (Pain, 2016).

Stan Jones, the founder of Complete College America, advocated for corequisite education, “not a prerequisite sequence” (Jones, 2015, p. 26) and pushed state legislators to enact these policies. In a study of three community colleges within the City University of New York (CUNY) system, Logue et al. (2016) randomly placed students who required developmental mathematics courses into a traditional elementary algebra course, an elementary algebra course with a weekly workshop, or into a college-level statistics course with weekly workshops. The workshops for the college-level statistics course assisted students with algebra concepts that were necessary to learn the statistics material. The researchers discovered that students in the college-level statistics course were 14% more likely to pass their assigned course than those placed into the traditional elementary algebra course and 11% more likely to pass than those placed into the elementary algebra course with workshops (Logue et al., 2016). It should be noted, however that this study only examined students who required statistics for their major and, therefore, cannot be generalized to students who are required to take college algebra.

In Florida, where students can now directly enroll in college-level mathematics courses, bypassing any developmental courses, Pain (2016) ascertained that 49.9% of students passed their college-level course, compared to 61.1% who passed when developmental coursework for students with low-level assessments scores was required, a statistically significant decline. However, students who enrolled into college-level mathematics courses increased markedly, causing concern that “a successful policy will likely be defined as increased completion, which could easily mean the weaker students are simply no longer in the data" (Pain, 2016, p. 939). Finally, another study of Florida showed that students assessed as needing developmental mathematics courses, but chose to enroll directly into college-level courses passed at a rate of 40.8%, compared to 48.2% of students who voluntarily enrolled in developmental mathematics corequisite courses (Park et al., 2018). It should be noted that these studies in the state of Florida identified intermediate algebra as college-level mathematics, while this course is widely deemed to be a developmental course among educators, as it is one level below college algebra. True mainstreaming may lead to a dramatic decrease in college-level mathematics success rates and corequisite models show increases in success rates, although these are most clear for statistics students. Future research on this model of redesign should examine students in STEM majors who require college algebra as well as success rates in college algebra compared to intermediate algebra.

### ***Modularization***

Modularization is common among redesign models of developmental mathematics. The mathematics curriculum is sorted into competency modules for students to study and complete as needed and at their own pace, instead of traditional semester courses (Hagedorn & Kuznetsova, 2016). The intent of this redesign is to allow students to study only mathematical concepts that they lack as well as move at an accelerated pace, shortening the time spent in developmental coursework (Rutschow, 2019b). This model is highly dependent on technology and also risks reduced "quality of the interaction between students and instructors" (Rutschow, 2019b, p. 13).

In their study of the modularized developmental mathematics program at Foothill College in California, Silverman and Seidman (2011) found increased rates of passing a college-level mathematics course after mastering the necessary modules in developmental mathematics (9%) compared to students in the traditional course sequence (3%). This program redesign utilized a combination of instructors and peer tutors to answer questions during the ten hours per week that the students worked in class (Silverman & Seidman, 2011). In addition to the extended time spent in class, the program offered study skills instruction that directly applied to their mathematics course, leading the researchers to conclude that "[t]he comprehensiveness and integration of the program, more than any individual component, is likely to be the source of its causal effect on student success" (Silverman & Seidman, 2011, p. 279).

In Tennessee, Jackson State Community College (JSCC) and Cleveland State Community College (CSCC) both adopted modularized models of developmental mathematics (Boatman, 2012). CCSC collapsed all developmental mathematics courses into smaller modules that allowed students to immediately begin the subsequent developmental mathematics course after successfully completing all the modules in their first course. JSCC combined all three of their developmental mathematics courses into twelve modules and then customized which modules students were required to complete based on assessment and career goals. Boatman (2012), using a regression discontinuity design, revealed that students near the cut-off at CSCC had increased persistence to their second semester and increased total credits completed compared to students enrolled in the prior traditional developmental mathematics program, although these differences disappeared over time. However, students at JSCC had similar outcomes to students in the previous program (Boatman, 2012).

The North Carolina Community College System implemented a modularized redesign to their developmental mathematics program by collapsing curriculum of three semester-long courses into eight 4-week courses (Bishop et al., 2018). This change provided the possibility for students to complete their entire developmental mathematics sequence in one year. Bishop et al. (2018) compared pass rates in college-level mathematics courses of students from the previous traditional developmental mathematics courses with those enrolled in the new modularized redesign, 62.93% and. 62.88% respectively. A weighted chi-squared test did not show a statistically significant difference between the traditional and modularized models and pass rates of college-level courses; however, the researchers noted a benefit to the redesign is reduced calendar time spent in developmental mathematics (Bishop et al., 2018).

Ariovich and Walker (2014) used both quantitative and qualitative research designs to examine the effects of modular developmental mathematics courses at a large community college, where students were given the option of enrolling in a traditional sequence of courses, or the new modularized courses. Students in the modular courses had an overall successful completion rate (a grade of B or higher) of 28% while students in the traditional sequence had an overall rate of 37% of students completing with a grade of B or higher (Ariovich & Walker, 2014). However, despite this difference, students in the modular courses were more likely to pass their subsequent developmental mathematics course than students in the traditional sequence, 54% and 34% respectively (Ariovich & Walker, 2014). The mixed quantitative results led researchers to examine qualitative data by interviewing students and instructors about their experience with the redesign. Although both students and instructors found the individualized level of instruction to be beneficial, both highlighted the need for more quality interactions between instructors and students (Ariovich & Walker, 2014).

The success outcomes of students enrolled in modularized developmental mathematics programs is mixed. Although some students experienced similar or higher passing rates of developmental courses (Silverman & Seidman, 2011) and college-level courses (Bishop et al., 2018), the literature demonstrates that others could benefit from more personal interactions with instructors and other students (Ariovich & Walker, 2014; Silverman & Seidman, 2011).

### ***Pathways Models***

Pathways models of redesign in developmental mathematics separate mathematical curricula and concepts based on areas of students' studies. Some pathways models separate the required developmental and college-level mathematics courses into three pathways, STEM pathways, quantitative literacy pathways, or statistics pathways. The intent of this redesign is to contextualize mathematics and corresponding high-level critical thinking skills in areas that students will use in their majors and/or careers (Merseth, 2011). Other than the traditional college-algebra pathway, students whose majors require a college-level statistics course can enroll in a course or sequence of courses designed to focus on statistical concepts with only the necessary prerequisite algebra needed for success in the course, such as the Path2Stats program in California (Hern & Snell, 2014) or the Statway™ program designed by the Carnegie Foundation for the Advancement of Teaching (Merseth, 2011; Rutschow, 2019b). Humanities students can enroll in a quantitative literacy course which gives them a survey of relevant mathematical topics, such as statistics, finance, and reasoning, such as Quantway™ and mathematics pathways designed by the Charles A. Dana Center at the University of Texas at Austin (Ganga et al., 2018; Merseth, 2011).

The California Acceleration Project (Hern, 2012) began with Katie Hern and Myrna Snell, resulting in the Path2Stats class in 2009 at Los Medanos College in California to help students reach their college goals faster and with more success. This course included basic statistical concepts that the students need to be successful in their college-level statistics course, while addressing algebra concepts as needed. Hern (2012) conducted a study of three years of the Path2Stats students and compared them to three years of students in the traditional pathway that leads to college-level mathematics. She determined that 60% of the Path2Stats students passed their college-level statistics course within one year while only 21% of students in the traditional developmental mathematics pathway passed their college-level mathematics class. Additionally, students whose assessment placed them in the lowest-level course of mathematics, 38% of students enrolled in Path2Stats passed their college-level statistics course compared to 9% of students in the traditional developmental mathematics sequence (Hern, 2012). The founders of this program noted, however, that accelerated programs must include much more than just a shorter pathway through the developmental mathematics process. They must include support for non-cognitive issues for students who may not be overburdened by the content of the mathematics concepts, but rather are confronting other difficulties in their life that prevent success in their courses (Hern & Snell, 2014). Other pathways models showed positive effects for non-STEM students in college-credits earned (Logue et al., 2016; Rutschow et al., 2017) and completion rates of college-level mathematics courses (Rutschow et al., 2017).

***Compression Models***

Compressed programs consolidate the material taught over multiple semesters into fewer semesters, sometimes even down to one semester (Edgecombe, 2011). This does not necessarily change the number of in-class hours because the number of credits often remains the same, but the material is covered in fewer weeks than a traditional semester. This allows students to complete in one semester what used to take two or more semesters to achieve. The nature of this type of acceleration allows for some additional advantages for teaching these courses. The increased amount of time spent for each class period allows for changes to pedagogy that increase student success. For example, instructors can spend more time on enrichment of the material and to observe in greater detail the level of understanding of their students (Edgecombe, 2011). Compression can also allow students to register for more than one course per semester, decreasing the number of times they must make the decision to enroll in a developmental mathematics course.

One study showed that a 4-week compressed redesign of the lowest-level developmental mathematics course led to increased common exit exam scores, but that students did not pass their college-level mathematics course at higher rates (Guy et al., 2015). Another study concluded that students in compressed developmental mathematics courses in Texas were 12% more likely to complete their entire sequence than students in traditional semester-long courses (Weisburst et al., 2017). A study conducted by Sheldon and Durdella (2010) of a large community college in Southern California where developmental mathematics courses were compressed into 6-week and 8-week terms showed increases in student success. Pass rates of the lowest-level 6-week, 8-week, and full semester developmental mathematics courses were 58%, 50%, and 48% respectively. Pass rates of the second lowest-level 8-week developmental mathematics course had a 67% pass rate, compared to 54% of students in the semester-long course (Sheldon & Durdella, 2010).

The FastStart program at the Community College of Denver is another example of a compressed redesign. The previous 3-course developmental mathematics sequence was modified to combine two sequential courses into a single semester. This program also implemented student support structures such as learning communities, intensive advising, and wrap-around services to meet the holistic needs of the students (Bragg et al., 2010). Edgecombe, Jaggars, et al. (2013) determined that 49% of FastStart students compared to 29% of students in traditional courses, had completed their assigned developmental mathematics sequence. They also saw that 33% of FastStart students, compared to 18% of students in the traditional sequence, completed their first college-level mathematics course within three years (Edgecombe, Jaggars, et al., 2013). Jaggars et al. (2015) used a regression model and analyzed data using other methods to control for the type of students who may choose the accelerated option of the program. They demonstrated that students enrolled in the FastStart program were 11% more likely to complete their first college-level mathematics course than students who took the traditional path (Jaggars et al., 2015). However, it should be noted that none of these researchers distinguished between college-algebra and statistics courses, as the college-level mathematics course that was studied.

Finally, Southwest Virginia Community College (SWCC) offered the three courses in their developmental mathematics sequence in both 5-credit formats and 3-

credit formats. Both formats required the same concepts and material be covered, but with a difference in the number of contact hours students spent with the instructor each week. Woodard and Burkett (2010) collected data from The Institutional Research Office of SWCC to compare the 5-credit course outcomes with the 3-credit course outcomes. They ascertained that the reduced amount of time showed no statistical difference in student success outcomes and, therefore, concluded that most students were able to master the same concepts in the 3-credit course as the 5-credit course (Woodard & Burkett, 2010).

***Shortened Sequence Length Models***

Shortened sequence length models of developmental mathematics are similar to compression models in that it reduces the amount of calendar time to complete the sequence; however, this is accomplished eliminating courses from the sequence as opposed to shortening term length (Edgecombe, 2011). Reducing the number of courses within a developmental mathematics sequence requires a redesign of the entire program and each course in it. This typically involves eliminating overlap that can be found between sequential courses, as well as eliminating concepts deemed unnecessary for student success in their college-level mathematics course. This, combined with an increased pace of instruction, results in a shorter developmental mathematics sequence (Hagedorn & Kuznetsova, 2016). Previously, in this literature review, many studies were discussed that examined sequence length and student success outcomes; however, there were surprisingly few studies that examined redesigned shortened sequences and their student outcomes compared to students in the same institution who enrolled in the previous traditional length sequence; which is a gap that this study helps to fill.

Middle Tennessee State University (MTSU) implemented a shortened sequence length model of redesign to their developmental mathematics program by combining the previous 2-course sequence into one course with two required lab hours each week. This program also created a college-level mathematics course with lab hours specifically for students enrolled in the new developmental mathematics course. The major finding of the Lucas and McCormick (2007) study of MTSU showed that there was no statistical difference between student success levels for students in the developmental mathematics course and then college-level course, compared to their traditional counterparts (Lucas & McCormick, 2007). The researchers concluded that the students were able to learn the material necessary for their college-level mathematics course in one semester just as well as those who took two semesters to learn the material. Another finding was that 71% of students in the new college-level mathematics course passed while just 57% of students passed who had taken a traditional developmental mathematics course and then enrolled in the traditional college-level mathematics course (Lucas & McCormick, 2007). This model of redesign is different from the model at UVU, in that MTSU designed their shortened sequence for students who then continued to receive additional supports in their college-level coursework as well.

El Camino College, as part of a holistic redesign that involved better alignment between K-12 mathematics and college-level courses, shortened their developmental mathematics sequence from four courses to two. A report illustrating student progression through the accelerated sequence showed that 0.2% of students in the traditional 4-course sequence passed a college-level mathematics course within two years compared to 15% of students in the accelerated program (*El Camino College math progression and* *completion: Accelerated math [ Fall 2011-Summer 2014 ]*, 2015). However, it should be noted that students in the lowest-level course of the traditional sequence included in this report would have had to take five semester-long courses (four developmental mathematics and one college-level mathematics) in two years compared to three semester-long courses in two years that the students in the redesigned sequence.

In Texas, 20 community colleges implemented Dana Center Mathematics Pathways to improve students' progress to degree completion. However, this model included a shortened sequence for developmental mathematics prior to the college-level pathways course, college algebra, statistics, or quantitative reasoning. This shortened the developmental mathematics sequences from three or two courses to just one course. The program also included additional advising that encouraged students to enroll in their college-level mathematics course immediately after completing their developmental mathematics requirements. Schudde and Keisler (2019) examined outcomes of over 6,000 students in the new one-course developmental mathematics program and over 9,000 students in two or three course developmental mathematics sequences from these 20 community colleges. Their analysis showed that students enrolled in the one course redesign were 46.9 % more likely to complete a non-college algebra course within two years than those enrolled in a two or three course sequence. However, students in the one course redesign were about 1% less likely to complete the college algebra course compared to students in the two or three course sequence (Schudde & Keisler, 2019). This finding demonstrates the possible benefits of shortened sequence length for non-STEM students but calls into question the effects on students required to take college algebra. The Schudde and Keisler study did not examine the effects of a shortened sequence on student success outcomes for students assessed at the lowest-level of mathematical ability. This study analyzed the effects of a shortened developmental mathematics sequence on students who require the most intervention to bring their mathematical knowledge and skills up to college-level readiness.

A dissertation by Martinez (2018) analyzed student success outcomes for students in a previous 4-course developmental mathematics sequence with students in a redesigned two course sequence at a California community college. He established that 7.4% of students placed into the lowest-level course of the previous 4-course sequence completed their developmental mathematics sequence, 2.3% passed a college-level mathematics course, and took an average of 3.03 years to pass a college-level mathematics course. Similar mathematical ability students who enrolled in the redesigned 2-course sequence had improved outcomes with 71.1% completion of the developmental mathematics sequence, 28.9% passed a college-level mathematics course, and it took an average of 2.01 years to pass a college-level course (Martinez, 2018). This demonstrated a dramatic improvement in student success outcomes, although it should be noted that students self-selected into the traditional 4-course or redesigned 2-course accelerated sequences, which could mean that more motivated students chose the accelerated model. The accelerated courses included extended time in the classroom and the curricula of these accelerated courses involved noncognitive activities, including “self-belief, positive habits, and other student success activities” (Martinez, 2018 p. 64). Although this dissertation examined years to completion of a college-level mathematics course, it did not examine semester to semester retention, whether students drop out during their first and second semester, or student grades in these courses.

***Summary of Redesign in Developmental Mathematics***

The multitude of developmental mathematics redesigns implemented across the country are diverse and involve various changes to placement measures, course and sequence structure, pedagogical strategies used in the classroom, faculty development, increased reliance on technology. They also involve changes/additions to student support structures, such as tutoring, learning communities, advising, and study skills workshops or courses (Ganga et al., 2018; Hagedorn & Kuznetsova, 2016; Rutschow, 2019b). The unique set of components that each developmental mathematics program redesign implements complicates research of their effects on student success outcomes. The success and/or failure of students in developmental mathematics is a complex and nuanced issue with multiple mechanisms at work, restricting the identification and understanding of the causal nature of these factors on student progression and achievement (Hodara, 2013; Martinez, 2018; Rutschow & Schneider, 2011).

State legislature mandates and non-governmental initiatives all intended to improve attainment rates for developmental students also have unique recommendations and requirements. States such as California, North Carolina, and Utah require colleges use multiple measures for placement assessment (Ganga et al., 2018; Utah H.B. 196, 2015). Texas and Tennessee mandate that students requiring developmental education be co-enrolled in college-level courses (Denley, 2016; Ganga et al., 2018; Texas H.B.2223, 2017). Florida allows students to decide on enrollment into developmental coursework despite their placement exam scores (Pain, 2016; Park et al., 2018). Missouri, New York, and Texas are encouraging pathways programs for students outside of STEM majors (Ganga et al., 2018; Rutschow et al., 2017). Additionally, non-governmental organizations and initiatives have their own recommendations. *Achieving the Dream*, founded in 2004 by the *Lumina Foundation for Education*, recommended strategies such as increased tutoring, advising, learning communities, and supplemental instruction (Hagedorn & Kuznetsova, 2016; Rutschow et al., 2011). *Completion by Design*, founded by the *Bill and Melinda Gates Foundation* in 2010 suggested integrated student supports, advising, student success courses, contextualized content, and less time spent in developmental education courses (Ganga et al., 2018; Grossman et al., 2015). *Complete College America* was founded in 2009 by Stan Jones to build an alliance of states together in their efforts to improve college completion rates. This initiative promoted five "Game Changers" including performance funding, requiring colleges to demonstrate satisfactory completion rates, credit accumulation and other measures of student success to receive money from state budgets; corequisite developmental courses, eliminating stand-alone developmental sequences in favor of supported college-level courses almost entirely; encouraging students to take 15 credits per semester of college, increasing credit accumulation; structured schedules, limiting course taking options and focusing students on required courses; and guided pathways, providing students with a clear coursework progression toward a degree (Complete College America, 2012, 2014; Jones, 2015). Varying requirements and recommendations from state to state, organization to organization, and initiative to initiative creates confusion for faculty and administrators looking to improve success rates for their developmental students and the costs of multi-faceted redesigns can be daunting to states and colleges.

In *Achieving the Dream*'s report on the first five years of its *Community College Counts* initiative, Rutschow et al. (2011) contributed the lack of improvements on student achievement gains to the limited implementation of strategies and the fact that the "majority of strategies at these schools remained small in scale, leaving large proportions of students relatively untouched by the colleges' *Achieving the Dream* work" (Rutschow et al., 2011, p. 13). In other words, colleges where only some components of a redesign are implemented may not see improved student achievement gains. Hodara (2013) stated that the long-term endurance of partially implemented redesigns in developmental education is uncertain and that "structural changes to the developmental sequence may have limited effects, but the combination of structural, curricular, and pedagogical changes to a developmental math sequence as well as the provision of non-academic supports can impact the college success of students in long-lasting, meaningful ways" (Hodara, 2013, p. 29). Hodara (2011) also recommended that more research be done which links the effects of specific pedagogical interventions in developmental mathematics reforms with student populations and student subgroups.

Rutschow (2019b) in her thorough review of developmental mathematics redesigns, commended reforms that "integrate supports such as intensive advising, accelerated developmental education, financial assistance, and more structured pathways toward completion… provided to students throughout their college career" (p. 19), suggesting that holistic redesign models of developmental mathematics have the greatest chance of success. City University of New York's (CUNY) Accelerated Study in Associates Programs (ASAP) is an example of holistic reforms designed to support students to overcome all obstacles in their path to achievement. The ASAP program required students to enroll full-time, but also provided wrap-around services such as intensive advising, tutoring, study skills courses, learning communities, career counseling, and even tuition waivers (Rutschow, 2019b; Scrivener et al., 2015). In addition, the CUNY Start program focused on developmental students and employed contextualized content in developmental courses, active learning, supplemental instruction, and a cohort style progression of developmental courses.

Scrivener et al. (2015) discovered that 40% of students in the ASAP program completed an associate's degree within three years, compared to 25% of students in traditional college programs. Developmental mathematics program redesigns that are holistic in nature, such as CUNY's ASAP or Community College of Denver's FastStart program, lead to more improved outcomes in student success (Edgecombe, Jaggars, et al., 2013; Scrivener et al., 2015; Sommo & Ratledge, 2016) than redesigned programs that incorporate only structural or acceleration changes and strategies (Ariovich & Walker, 2014; Bishop et al., 2018; Geltner & Logan, 2000; Guy et al., 2015; Hodara & Jaggars, 2014; Park et al., 2018).

Lastly, a qualitative study (Cox & Dougherty, 2019) of developmental mathematics students in a recently reformed program pointed a spotlight to the disparity between the ways student success in developmental courses has traditionally been measured and actual student learning. Cox and Dougherty (2019) related students' goals for their developmental mathematics coursework and their reported mathematical learning, stating "the measures that have highlighted the inadequacies of developmental math are, in themselves, insufficient for assessing the effectiveness of reforms to developmental math" (p. 245). Although the goals of both the instructors and students included an increase in the students' understanding of the relevance of mathematics and an increase in real mathematical knowledge and the intricacies of algebraic exploration and manipulation in problem solving, very few students reported learning much from their developmental mathematics courses. Students did not see the mathematical concepts as useful in their everyday life, nor did they believe that they had a greater understanding of mathematics, but rather just felt "refreshed" on prior mathematical learning (Cox & Dougherty, 2019). The researchers pointed to the "highly procedural curriculum enacted" in the classrooms, despite complete redesign of the developmental mathematics program (Cox & Dougherty, 2019, p. 259) and restated concerns that measuring students' completion rates of developmental mathematics courses does not necessarily assess or reflect student learning.

**Demographics of Developmental Students**

Developmental students are a subpopulation of college students, with their own diverse and unique needs. Various studies from different years, although each using different data and reporting slightly different numbers, demonstrate the demographics and characteristics of developmental college students. Additionally, a majority of community college students entering college for the first time enroll in at least one developmental course over their college career, with 68% of students at 2-year institutions taking a remedial course, compared to 39.6% at 4-year institutions (Chen, 2016).

***Ethnicity***

There is racial diversity among developmental students. Boylan et al. (1994), in their study of National Study of Developmental Education data, found that at 2-year colleges, 67% of developmental students were White, compared to 23% African American and 6% Latino; and at 4-year colleges, 59% of developmental students were

White compared to 30% African American and 7% Latino (Boylan et al., 1994). In a study of NELS:88 data, Attewell et al. (2006) observed that non-Hispanic Black students had a 61% probability of enrolling in developmental courses, compared to 35% of non-Hispanic White students (Attewell et al., 2006). Finally, among students who first enrolled in a 2-year college in 2003, 78% of Black students enrolled in a remedial course, compared to 75% of Hispanic students and 64% of White students. At 4-year institutions, 66% of Black students enrolled in a remedial course, compared to 36% of White students and 53% of Hispanic students (Chen, 2016).

This data showed that, although the majority of developmental students are White, a disproportionate number of minorities end up in these courses (Chen, 2016). This is concerning, given that black students are 1.75 times more likely than White students to drop out (Feldman, 1993). Additionally, 15.3% of White students earned an A in their remedial course, compared to 6.6% of Black students; additionally, 35% of White students earned an F or withdrawal, as compared to 48.3% of Black students earning an F or withdrawal. This further emphasizes the disparities of race in developmental education (Bahr, 2010b).

***Age***

The age of developmental students, whether traditional or non-traditional, also appears to affect student success outcomes. The mean age of developmental students at 2-year colleges is 23 years old, compared to 19 years old at 4-year institutions. Although the sample used in this study ranged from 16-55 years old, the majority were between the ages of 18 and 24 years old (Boylan et al., 1994). Chen (2016) determined that at 4-year colleges, 16% of developmental students were older than 24 years old, with 37% 19 years old and 37% 18 years old. Developmental students, although the majority traditional in age, can also be non-traditional. Feldman (1993) detected that students least likely to drop out were those 25 years of age and older, followed by 19 years old and younger, then students aged 20-24. However, Calcagno et al. (2007) discovered that students aged 25 or older were less likely to graduate than younger students. Although, after controlling for mathematical ability, older students were 1.24 times as likely as younger students to complete a degree (Calcagno et al., 2007). This suggests that time away from mathematics courses plays a bigger role in predicting student success than age itself.

***Sex***

The sex of developmental students follows rates of college students in general. Boylan et al. (1994) found that developmental students at 2-year colleges were 53% female, compared to 54% female at 4-year colleges. Chen (2016) revealed that at 2-year institutions, 71% of female students enrolled in a developmental course, compared to 65% of males, although there was no difference at 4-year institutions. These trends mirror national demographics of sex in colleges. Feldman (1993) observed that sex was not related to persistence in college when controlling for other factors.

**Lowest-Level Placed Students**

Students entering college with the lowest levels of mathematical ability require the most assistance to become college ready and are at the greatest risk of dropping out (Bahr, 2010a; Bahr, 2008, 2012; Boatman & Long, 2018; Brower et al., 2018). In his book, *Back to School*, Mike Rose (2012) discussed issues of access to higher education for the lowest-level placed students and the need to "create the conditions for them to thrive once inside" (p. 143). Developmental education programs may be the "only for them to further their education" and through these programs and the colleges that offer them "we can get a measure of how we're doing as a society on a number of questions that are fundamental to our best sense of who we are" (Rose, 2012, p. 9).

### *Mathematical Ability Divide*

The divide between college students with the lowest levels of mathematical ability and students still requiring developmental mathematics coursework, but have higher levels of mathematical ability, can make it difficult to research the effectiveness of programs on all developmental students. In Florida, where developmental mathematics coursework is optional the students with low levels of mathematical ability who still enrolled in developmental mathematics classes performed better than those who immediately enrolled in college-level mathematics courses (Brower et al., 2017; Pain, 2016). Bahr (2008) determined developmental mathematics coursework was equally effective for students with both higher and lower levels of mathematical ability and their attainment of success, but also noted that the lowest-level placed students who did not complete their developmental mathematics sequence suffered the most detrimental consequences, suggesting additional needs of the lowest-level placed students. However, Bahr (2010a) later determined that the likelihood of persistence among the lowest-level placed students was a more powerful factor in student success outcomes than initial course placement, stating "the relationship between persistence and successful remediation varies across the range of persistence and across levels of initial math deficiency" (Bahr, 2010a, p. 41).

In a qualitative study of at-risk students in developmental mathematics, Brower et al. (2018) showed that scaffolding of the mathematics curriculum could be beneficial to students with the lowest levels of mathematical abilities. Developmental mathematics courses instructors used scaffolding pedagogical methods to help students reach college-level readiness and the researchers suggested that mathematical concept scaffolding should be fully integrated with student support structures. Additionally, the researchers stated “we must work harder to meet the need for mathematics remediation through comprehensive efforts to scaffold the curriculum” (Brower et al., 2018, p. 125). However, despite the increased need for individualized scaffolding approaches to developmental mathematics, students with the lowest levels of mathematical ability are also the least likely to have access to multiple models of developmental mathematics content delivery (Kosiewicz et al., 2016). Most alternative methods or redesigns of developmental mathematics programs were only available to “those on the cusp of college readiness rather than those students who may need it most” (Kosiewicz et al., 2016, p. 226).

***Outcomes for Lowest-Level Placed Mathematics Students***

The student success outcomes for students with the lowest levels of mathematical ability are often mixed, and while these students have the most to gain from developmental mathematics programs, they disproportionately do not succeed in completing their developmental mathematics sequences and, subsequently, suffer higher rates of attrition (Bailey et al., 2010). Studies of the efficacy of traditional developmental mathematics programs for students with the lowest levels of ability have had mixed results. Boatman and Long (2018) analyzed longitudinal data for students enrolled in 2-year and 4-year colleges in Tennessee and used a regression discontinuity research design to examine the effects of developmental mathematics on students at the cut-off of each course in the developmental mathematics sequence. Although students just below the college-readiness cutoff were 9.3% less likely to enroll the following year, 5.3% less likely to earn an associate's degree, and 6.2% less likely to earn a bachelor's degree, students placed into the lowest-level course of developmental mathematics did not have statistically significant differences in enrollment rates the next year, in passing college-level mathematics rates, in credit accrual, or in degree attainment (Boatman & Long, 2018). In another regression discontinuity research design study, Xu and Dadgar (2018) also examined students near the cut-off between the lowest-level developmental mathematics course and the second-lowest-level course. They found that placement into the lowest-level course slightly reduced the likelihood of degree attainment, but seemed to have no effect on passing a college-level course, and concluded that students near the cut-off gain little benefit from the lowest-level developmental mathematics course (Xu & Dadgar, 2018). However, both studies only showed the effects for students near the cut-off scores between levels of developmental mathematics course placement and cannot be generalized to students who place well below the cut-off score.

Studies of the effects of redesigned developmental mathematics program models and students with the lowest levels of mathematical ability also showed mixed results. In a study of four universities and five community colleges across Texas, Booth et al. (2014) analyzed outcomes for compressed and modularized models of redesign in developmental programs and observed that the higher-level mathematical ability students had better outcomes, stating that students with lower levels of mathematical ability "were not able to handle the self-paced learning process" (p. 4) and needed a more traditional approach to developmental mathematics. Martinez (2018) discovered statistically significant increases in student success for students assessed at the lowest levels of mathematical ability when the developmental mathematics sequence was shortened from four courses to two courses (2.3% passed a college-level mathematics course in the 4-course sequence compared to 28.9% in the 2-course sequence, Martinez, 2018).

Given issues of low retention and successful completion for students with the lowest levels of mathematical abilities, the current push for accelerated models of redesign in developmental mathematics leaves more questions to be asked than it answers. Cafarella, (2016b) stated that these models are "clearly suited for students who require minimal help" (p. 62) and that the "continued lack of student responsibility" (p. 63) must be addressed to improve student success outcomes in developmental mathematics. These conflicting findings in the literature for students with the lowest levels of mathematical ability describe a need for more research on this group of developmental mathematics students, such as this study, and how to best address their needs and assist them on their path to college success.

**Assessment and Placement**

College policies of assessment and placement in developmental mathematics programs is a complex issue. From entry exams to registration, students, faculty, and administrators must navigate through combinations of policies, procedures, exam scores, adviser suggestions, and more to determine the correct placement into a developmental mathematics course. In their case study, Melguizo et al. (2014) examined the assessment and placement practices of the Los Angeles Community College District (LACCD) from 2005 to 2007. The authors used a mixed methods approach to evaluate data from transcripts, exam scores, administrative documents, websites, and interviews. They saw that most colleges in LACCD used the ACCUPLACER or COMPASS to provide an initial placement score and then added multiple measures such as high school mathematics level, time since last mathematics class, high school GPA, and sometimes the effort and time students were willing to give to their college mathematics courses. However, despite what appears to be a thorough assessment and placement procedure, researchers observed exam cut scores and point values for multiple measures to be set without proper consideration or full understanding of the consequences. Additionally, the use of multiple measures was inconsistent across colleges in the district and only 6% of all students moving up a level in mathematics courses as a result of these measures (Melguizo et al., 2014). Furthermore, faculty and administrators responsible for evaluating and implementing assessment and placement policies were not equipped with the resources or technical skills necessary to be fully effective. The authors concluded that, although unable to state with certainty that these practices actively harmed students, there was much room for improvement and encouraged consistency across the district.

Another case study (Safran & Visher, 2010) examined the assessment and placement policies and practices at three community colleges. Specifically, the researchers looked at which students were required to take a placement exam, which placement exam was used, if students could retest, and how much weight the exam scores were given consideration of placement in a developmental course. Across the colleges, there were inconsistent understandings of college-readiness and how best to place students. Cut scores for the standardized assessments varied and students who took these exams were often unprepared or even unaware of the testing requirement. The researchers also discovered that, at the college that used multiple measures for placement, counselors still based placement almost entirely on the exam scores, using additional measures as validation of original placement or questioning the subjective nature of multiple measures and their ability to improve accurate placement (Safran & Visher, 2010). Additionally, the results of standardized placement exams were not used to determine instruction, nor did the content of the exams align with the curriculum of developmental courses. Furthermore, there were no consistent procedures to evaluate or revise placement policies such as cut scores and some procedures involved very little input from faculty. Finally, the authors determined that tradition or convention defined many assessment and placement policies rather than data or validation of these policies. They concluded that despite acknowledgement of room for improvement, colleges were reluctant to change as they “strive to streamline admissions and enrollment activities to maximize the open-door ethic of the college” (Safran & Visher, 2010, p. 21).

Heavy reliance on a college entry placement exam leads to questions of the predictive power of these tests. Scott-Clayton (2012) examined the validity of placement based on the COMPASS standardized test using regression analyses and predictive variables such as placement test scores, years since high school, and high school GPA for four cohorts of first-time college students at LUCCS. The researcher determined that the placement exam score only explained about 13% of the variation in mathematics course grades and less than 2% of English grades. Although when compared to open student access to college courses, the use of exam scores is an improvement, Scott-Clayton found that the use of high school GPA alone, in place of any placement exam, was a better predictor of student success in college-level mathematics courses and only saw incremental improvement with the addition of placement exam scores. Notwithstanding, Scott-Clayton’s model using multiple measures still “comes far from eliminating severe placement mistakes" (Scott-Clayton, 2012, p. 33). The author suggested that the use of even more measures, including non-cognitive factors, may help to place students more accurately in developmental courses, or directly into college coursework. A similar study that examines the COMPASS, and ACCUPLACER exams (Scott-Clayton et al., 2014) compared the predictive ability of placement based on these exam scores alone with placement based on high school achievement along and a combination of the two variables. The results highlighted the difficulty of predicting college success in any scenario. Although still not a strong predictor of success, high school data still was a more powerful predictor than the placement exam scores.

However, it is important to note that some of this research may have used fundamentally flawed methodology. Morante (2013) pointed out issues of correlational research which requires a normal distribution, a requirement which was not met in some studies (Scott-Clayton, 2012; Scott-Clayton et al., 2014). Additionally, Morante highlighted the fundamental flaw of examining predictive power of placement tests is that these tests were not designed to be predictive of college success or grades in college courses. He cautioned against the use of these studies to undermine developmental education in its entirety and urged improvements to assessment and placement which are known to improve success. For example, a study of multiple measures used for mathematics placement by Ngo and Kwon (2014) of placement policies in the Los Angeles Community College District (LACCD) found that the inclusion of prior mathematics background and high school GPA predicted college success in terms of accumulated transfer credits, but not necessarily success in mathematics courses. This suggests that, although the inclusion of these measures can help improve placement accuracy, these measures should not replace all other measures, including placement exam scores. However, the authors also stated that despite the purpose of using multiple measures for placement is partly to minimize disproportionate placement into developmental coursework of minorities, these practices only slightly increased rates of access to higher levels of mathematics for African-American and Latina/o students (Ngo & Kwon, 2014). They concluded with the suggestion of increased use of non-cognitive measures to improve placement accuracy.

Experts in developmental education call for a much more comprehensive model for assessment and placement. Boylan (2009) suggested an intensive model to assess college-readiness using cognitive and non-cognitive profiles and assessments as a place to start. These student profiles would then be aligned with campus resources and instructional delivery, followed by continual evaluation of progress and revision of plans when necessary. Saxon and Morante (2014, 2015) urged a holistic approach with mandatory assessment, placement, and advising working in tandem to develop a plan for students based on an inventory of possible instruction and resources. They also cautioned against the interpretation of efforts to improve placement as part of an agenda to characterize developmental education itself as broken, emphasizing the potential benefits of accurate placement combined with interventions.

**First-Year Retention**

Retention of students in their first year of college is a vital step to helping students in overall college achievement and degree attainment. A sizable number of students drop out before ever reaching their second year (Fike & Fike, 2008). Tinto's theory of attrition states that students who feel integrated into the academic and social aspects of the institution are less likely to drop out. The first year experience of students is crucial in developing those feelings of inclusiveness and for students to be engaged.

***First Year Experience***

Using data from 30 4-year colleges with participants in the National Survey of Student Engagement (NSSE), Reason et al. (2006) sought to identify factors that shape the first year experience for students and understand which of these factors have the greatest effect on students' development of academic competence. The researchers concluded that "first-year students' perception of the support they received… was the single greatest influence on their development of academic competence" (Reason et al., 2006, p. 164). The students' sense of support from and sense of good relationships with instructors and staff during their first year directly led to increased engagement and improved academic and soft skills. This result suggests that institutions should "[i]nstitute policies and practices aimed at improving relationships" and should "adopt a holistic approach to supporting students" throughout their first year (Reason et al., 2006, p. 170).

Goldrick-Rab (2007, 2010) examined methods used to increase academic momentum for students and discussed the first-year experience, along with any developmental education experiences, that can increase persistence in the first year. Additionally, the author stated that certain courses, such as mathematics, can act as gatekeepers and "passing them may significantly contribute to student progress" (Goldrick-Rab, 2007, p. 13). The institutional structure and developmental education programs are probable contributors to the early success of students (Goldrick-Rab, 2010). Finally, using data from the National Postsecondary Student Aid Study (NPSAS), Sparks and Malkus (2013) analyzed enrollment in developmental coursework for first year students and showed that, although the percentage of students enrolled in developmental coursework their first year had increased from 2003-2004 to 2007-2008 (22.1% and 23.3%, respectively), the 2007-2008 enrollments were still markedly reduced from 1999-2000 when 28.8% of all students enrolled in developmental courses. However, the authors cautioned that these percentages may indicate an increased level of college readiness for incoming freshmen, or that there are other policies, such as placement into or even reduced opportunities for developmental programs, that may have contributed to this decrease as well (Sparks & Malkus, 2013).

***Developmental Mathematics and First Year Retention***

In a study of developmental education as it relates to attrition at a 4-year open enrollment institution using logistic regression, Hoyt (1999) determined that increased need for developmental coursework had a negative effect on student GPA. By extension, among all students, developmental or not, first-term academic performance was the strongest predictor of retention. This finding suggests that students need increased academic support to improve their overall GPA, particularly in their developmental classes. However, in a regression discontinuity design study, Lesik (2007) discovered that participation in developmental mathematics decreased the risk of dropping out compared to equivalent students who did not participate in developmental mathematics, with dropout rates of 8.2% and 27.7% respectively. Lesik stated that this finding suggests “that participating in the developmental mathematics course has a positive impact on student retention” and “that developmental education programs *can* be effective in helping to keep students enrolled in college” (Lesik, 2007, p. 605, original author's emphasis).

Scholars (Bremer et al., 2013), analyzed the effects of developmental mathematics coursework on retention using regression and logistic regression. The researchers ascertained that developmental mathematics coursework had no effect on student retention into the second term, nor into the second year of college, when other factors were controlled for. Although they also observed that students with higher mathematics placement scores were more likely to be retained across multiple retention outcomes (Bremer et al., 2013). Similarly, Crisp and Delgado (2014), in a study of community college students using data from the Beginning Postsecondary Students Longitudinal Study (BPS: 04/09), determined that enrollment in a developmental mathematics course in the first year had no impact on student retention into the second year, although it did have a negative impact on transferring to a 4-year institution. Descriptive statistics of the study suggested that "students who enroll in developmental courses are systematically different from community college students who do not remediate" (Crisp & Delgado, 2014, p. 111), thereby, measures of the effects of developmental coursework on retention may not be reliable (Crisp & Delgado, 2014).

***Predictors of First Year Retention***

Other statistical approaches to studying retention among first year students also showed mixed results. Hawley and Harris (2005), in their study of student characteristics that predict retention in the first year at Prince George's Community College (PGCC), discovered that the number of developmental classes a student is required to take is among the highest predictors of dropping out. However, the highest predictor of drop out was students' expectations of problems related English proficiency, indicating that attention should be paid to ESL students at PGCC. Other predictors of attrition were lack of focus on educational goals, lack of engagement in college campus activities, delayed enrollment after high school, employment obligations, and expecting problems to arise with finances (Hawley & Harris, 2005).

It is speculated that the mathematical ability levels of incoming first year students is one of the most consequential factor related to college success, including persistence (Bahr, 2008, 2009, 2010a; Bailey et al., 2010; Bremer et al., 2013; Burns, 2010; Conley, 2007; Hawley & Harris, 2005; Hoyt, 1999; Li et al., 2013); however, actual enrollment in developmental coursework appears to have almost no negative effect, and possibly some positive effect, on first and second year persistence (Bahr, 2008; Bettinger & Long, 2005a, 2005b; Calcagno & Long, 2008; Crisp & Delgado, 2014; Lesik, 2007). Other student characteristics that lead to improved persistence rates include race/ethnicity (Bahr, 2010b; Bailey et al., 2010; Fike & Fike, 2008, Wolfle, 2012), gender (Wolfle, 2012) and age (Fike & Fike, 2008; Kolajo, 2004). Finally, Tinto suggested that persistence in the first year for developmental students is mainly determined by developmental education programs (Engstrom & Tinto, 2008) and, therefore, "there is much to be gained from a rethinking of the character of those courses and the development of coherent first-year programs whose purpose it is to ensure that all students receive the support they need to learn and persist beyond that year" (Tinto, 2008).

**Other Relevant Studies**

A qualitative study conducted by Walker (2015) on faculty perceptions of accelerated developmental programs found that many faculty members experienced increased teaching rewards through improved student success and a stronger bond between faculty and students. Faculty recounted to the researcher that the accelerated programs increased their awareness of their students' learning abilities and struggles. Most faculty reported adjusting their pedagogy in the classroom and a changed perception of their students' motivations (Walker, 2015). It should be noted, however, that the positive perceptions of acceleration in developmental programs related to changes in pedagogy, strengthened bonds with students, and increased understanding of students' non-cognitive issues (Walker, 2015), are not unique to accelerated programs.

Another qualitative study conducted by Cafarella (2016a) on faculty opinions of acceleration offered unique insights into the practice of acceleration in developmental mathematics. The researcher surveyed six faculty members from three different community colleges with the general research question, "based on faculty experience, what is the best fit for the practices of acceleration and compression in developmental mathematics?" (Cafarella, 2016a, p. 14). The first major finding of this study was that accelerated programs that were initiated by faculty had much smoother transitions to the new models than those which were initiated by the administration (Cafarella, 2016a). Additionally, faculty felt that students placed into these accelerated programs needed to possess certain characteristics to be successful, such as comfort with technology, organizational skills, and a learning style conducive to self-paced courses. Furthermore, faculty members thought instructors must also be suited for the accelerated classroom, not just the students. Teachers who are better suited for the traditional classroom need not teach the redesigned courses but should be utilized in the traditional classroom where their skill-set is best employed. The final major finding of this study was that faculty consistently stated that not all students should be forced into accelerated developmental mathematics, as these programs work very well for many students, but can be detrimental to students who thrive better under a slower, more traditional model of instruction (Cafarella, 2016a).

Moreover, the success of accelerated developmental mathematics program redesigns may be hampered by a multitude of factors. Edgecombe, Cormier, et al. (2013) discussed many of these inhibiting factors in a study which examined qualitative data from colleges working to implement reforms to their developmental education programs. Some beginning challenges were “a reactive (as opposed to reflective) reform implementation process” (Edgecombe, Cormier, et al., 2013. p. 20) and concerns of grade inflation or a watering down of curriculum materials among faculty. Additionally, the authors acknowledged that student success outcomes are unlikely to be improved without “a systematic focus on strengthening individual and institutional resources in conjunction with reform efforts” (Edgecombe, Cormier, et al., 2013. p. 21). Furthermore, “haphazard implementation” (Rutschow, 2019b) of reforms which “lack mechanisms for reflecting on and counteracting implementation shortcomings… may partially explain why developmental education reform efforts to date have had limited impacts” (Edgecombe, Cormier, et al., 2013, p. 30). However, the high cost of holistic reforms (Sommo & Ratledge, 2016) may inhibit colleges from enacting reforms in the manner in which Edgecombe and her colleagues suggested. Educators may opt instead for “less intensive, less costly” models of redesign (Rutschow, 2019b, p. 23), resulting in limited, or possibly negative, effects on student success outcomes “particularly for students whose assessment results suggest lower-level skills in math” (p. 22).

Finally, there are many challenges that accompany the implementation of reformed developmental mathematics programs. Cafarella (2016c) conducted a qualitative study of ten faculty from five community colleges who had taught in an accelerated redesign program of developmental mathematics using an electronic questionnaire. The researcher revealed that many faculty members had misconceptions about the nature of acceleration and its implementation. First, faculty members expressed frustration with the amount of time it takes to fully implement and evaluate a reform, which, combined with frequent adjustment of the redesign, hindered the study of the effects on student success. Second, faculty recounted administrators who had the assumption that a redesign would act to "fix" all the problems of developmental mathematics. Rather, "the idea that student success rates in developmental math will surge and that students will complete their required course-sequence quicker is incorrect" (Cafarella, 2016c, p. 35) and "it is precarious to assume that one learning modality or practice can be extrapolated to all students (p. 36). Third, faculty members reported frustration with administrators who treated the enactment of these redesigns as "celebratory and festive occasion[s]" (p. 37) when the faculty were tasked with the hard work of actual implementation into the classroom. These findings highlight the need for a careful and methodical approach to any redesign of developmental mathematics programs.

Other challenges to various models of accelerated developmental mathematics programs were discussed by Saxon and Martirosyan (2017) in another qualitative study of faculty members. The challenges reported included the continuing issue of student attendance, a pace of instruction that can prohibit learning for some students, and the level of mathematical understanding that students may or may not achieve (Saxon & Martirosyan, 2017). The faculty members also gave recommendations for improvement in the implementation of a redesign. These included a change to pedagogical practices to compensate for incoming students' mathematical ability, increased and more intensive advising, and more accurate placement policies using cognitive and non-cognitive indicators (Saxon & Martirosyan, 2017).

## Conceptual Framework

Kulik and Kulik (1991), in their discussion of developmental instruction and the theoretical foundations of developmental education, created a conceptual framework of the purpose and role of developmental education. They defined what developmental education is, "college instruction that is adjusted in content, style, or pace to meet the educational needs of high-risk students" (Kulik & Kulik, 1991, p. 1), but also what developmental education is not, "giving [students] more of what they hated in high school" (p. 2). This adjustment of education for students who require assistance to reach the level of college readiness required for success must be tailored and adjusted to the students that it serves. The conceptual framework, which was used in this study to frame developmental mathematics, its purpose, and defining practices, such as the role of acceleration, mirrored the framework put forth by Kulik and Kulik and drew from multiple learning and instructional theories as grounding for adaptive teaching and the instruction of learning strategies. However, the conceptual framework for this study was focused on adaptive teaching and its elements, which provided possible reasoning for accelerated avenues through developmental mathematics.

***Developmental Education Programs***

Increased access to higher education gives more opportunity to students who are striving to improve their situation; however, it does come with challenges as well. Students who are underprepared for college-level coursework may need additional assistance to increase their chances of success. Developmental education programs are designed to fill this role by developing students who have the necessary skills, particularly in mathematics, reading, and writing, to accomplish their educational goals. Coursework in developmental education programs use “college instruction that is adjusted in content, style, or pace to meet the educational needs of high-risk students” (Kulik & Kulik, 1991, p. 1). There are multiple possible reasons for students to lack the skills that are necessary to succeed at a college-level. Shortcomings such as lack of basic preparation and proper motivation have previously been posited as such possible reasons (Cross, 1976; Maxwell, 1985); however, there are many cultural and social factors that contribute to a student’s educational outcomes (Boylan & Bonham, 1994; Boylan et al., 1994), which must be considered when building a developmental education program.

Holistic developmental education programs include more than just remediation to address deficient academic content skills. Faculty and administrators in these programs consider the needs of the whole student by providing coursework for academic skills; advising, counseling, and tutoring to help students navigate their educational path; and comprehensive support services to promote student achievement. Effective programs approach both cognitive and non-cognitive facets of student learning and provide support structures to help students combat individual stumbling blocks on their path to educational success (Rutschow, 2019b; Scrivener et al., 2015; Sommo & Ratledge, 2016). Furthermore, the initial designs and changes of the components of these programs should be grounded in learning and instructional theories. Kulik and Kulik (1991) specified adaptive teaching and instruction on learning strategies as two elements of developmental education programs which explain why these programs work to prepare students effectively and how to improve them. Thus, any changes to developmental mathematics programs should deliberately address or improve on adaptive teaching methods and learning strategies. Adjustments or changes to the overall structures of these programs without full consideration of the elements of learning theory that accompany these structures may be unproductive and ineffectual in exacting change or improvements in student success outcomes.

***Adaptive Teaching Methods***

Adaptive teaching is the antithesis of a "one size fits all" approach to education. It requires higher education institutions, programs, and instructors to identify beneficial methods of instruction and learning to match with the needs of their students. Students with differing ability, preparation, and learning rates require varying methods to effectively learn. They also have diverse characteristics and backgrounds and, therefore, exposing them to the same methods of instruction and assessment does not result in the same outcome for all students. Adaptive teaching uses the results of aptitude measures to "adjust instruction to such individual learner characteristics as learning rate, motivation, and personality" (Kulik & Kulik, 1991, p. 10).

Developmental education programs that utilize adaptive teaching methods would, therefore, provide alternative approaches and paths to learning for students "that match their individual characteristics: their past performance, background, talents, or interests"

(Kulik & Kulik, 1991, p. 10). These individual characteristics include the ideal rate of learning for each student and adaptive teaching allows for students to move through developmental education programs according to their individual learning rates. This includes accelerated developmental mathematics programs and providing a path for students to learn and build the necessary skills in less calendar time than is traditionally provided. However, this does not require that all students move through programs at an accelerated rate. This would be a gross misunderstanding of the benefits of adaptive teaching and personalized approaches to instruction and learning. Students can and do learn at different rates and this acknowledgement requires a variety of avenues to achieve college-level readiness. Practices that are in harmony with adaptive teaching can be found within two main traditions, measurement and experimental.

**Psychometric Measurement.** The measurement tradition relies on psychometric measurements as the result of assessments of learner ability. These results are examined and then used to place students in programs or pathways where they will be most likely to experience successful outcomes. "Psychometricians measure individual variation with tests, analyze it with correlational methods, and use their results to select individuals who are likely to succeed in specific settings" (Kulik & Kulik, 1991, p. 10). However, it should involve more than a simple grouping of students who have similar beginning levels of mathematical understanding based on placement test scores. Adaptive teaching adapts to the learner instead of forcing the learner to adapt to the teaching. This requires "special efforts to adjust curricular coverage and bring in special materials for special aptitude groups" (p. 12). Additionally, it requires that developmental mathematics programs provide more alternatives of curricula, delivery methods, and rates of material coverage to meet all manner of needs from a diverse group of students. Examples of this type of adaptive teaching include allowing students to set the pace of instruction and recognizing multiple ways of learning among students. Alternative speeds or calendar time to move through a developmental mathematics program to the speeds and calendar time in a traditional sequence can be beneficial for students when it addresses the various timing and learning needs of developmental students. Furthermore, instructional methods which consider numerous ways of learning and present concepts through a multitude of approaches also helps to reach developmental students by providing more personalized support than would be provided in traditional college courses.

**Experimental Control.** The second tradition of adaptive teaching involves a more scaffolded approach to teaching and learning where students, facilitated by a teacher, build on current knowledge to attain college-level skills and understanding. Frequent summative assessments, added structure, and additional feedback help to solidify the understanding of concepts in a student in this tradition (Kulik & Kulik, 1991). This requires adaptable instruction to provide individual students with the proper scaffolding and personalized pathways throughout their developmental coursework. Examples of this this type of adaptive teaching include increased technology use and student self-pacing through objectives. Computer-based instruction or any increase in technology use in a developmental mathematics course provides students with immediate feedback on their problem-solving strategies with an "infinitely patient tutor" that will provide constant guidance, "keep perfect record of its interactions" with each individual student, and is "always available" when students are able to work (Kulik & Kulik, 1991, p. 33). Additionally, self-pacing based on the needs of individual students requires adaptive teaching to help students prepare for frequent assessments and for students to reach necessary levels of understanding.

Regardless of the tradition, "[b]oth psychometricians and experimentalists hold that traditional educational approaches are too rigid and inflexible because they prescribe the same instructional conditions for all learners, no matter what their initial aptitude and no matter what their responses to instruction" (Kulik & Kulik, 1991, p. 11). Adaptive teaching is flexible and adjusts to meet the needs of all students, regardless of characteristics or backgrounds. Recognition of students as unique individuals requires adaptable approaches to learning and instruction.

#### ***Learning Strategies***

Instruction on learning strategies allows students to take a more active role in their learning processes and achievements. Developmental education programs should involve more than basic remediation through the presentation of content objectives. Many developmental students can benefit from training in these strategies for academic success and practice monitoring their learning and comprehension. Elements of learning strategies are introduced to students through student success courses, which explicitly instruct students on the effective use of these strategies (Edgecombe, Jaggars et al., 2013; Hagedorn & Kuznetsova, 2016; Weisburst et al., 2017); advising and counseling that provides guidance to students navigating college learning systems (Burns, 2010; Fike & Fike, 2008); tutoring and additional content assistance to help students reach their goals (Kosiewicz et al., 2016); and other support services which piece together a holistic developmental education program (Rutschow, 2019b). Although not the main focus of the current study's conceptual framework, accelerated developmental mathematics programs or sequences may provide learning strategy instruction for students through the addition of student support services to maintain student motivation and achievement in an environment where the pace of mathematical instruction is intensified.

***Summary of Conceptual Framework***

Developmental mathematics programs utilize elements of adaptive teaching methods and instruction of learning strategies to improve students' chances of college success. These elements are more than just isolated changes in teaching, program structures, or support services in developmental programs without the consideration of the diverse needs of a student population. Changes made to these programs that improve adaptive teaching and account for varying ways of learning are based on sound learning and instructional theory and have the potential to alter student behavior and, therefore, student outcomes. Accelerated programs of developmental mathematics that allow for multiple student learning rates and simultaneously increase student support services, provide formal instruction on learning strategies, and accommodate a diverse population of incoming students could very well improve success outcomes for underprepared college students. However, changes made to the elements of developmental mathematics programs without factoring in issues of individual students are just changes to the structures of the programs and unlikely to make any real change in student success outcomes. A major issue with advocacy of broad sweeping changes to developmental program structures and courses may force colleges, administrators, and legislators to assume that this practice is certain to improve the situation of their students. However, practitioners should be wary of changes to program elements that do not address these learning principles, as they may just be changes for the sake of change and not truly for the benefit of students. It is increasingly important that those in a position to enact these changes have a thorough "understanding of theoretical principles… because that understanding provides a framework within which we can be intentional about our choices as educators. It is the capacity to be intentional that makes us professionals" (McCrimmon, 1992, p. 3).

**Discussion of Literature**

The available literature on acceleration in developmental mathematics programs sometimes seems to contain contradictions, however, there are some patterns that emerge upon scrutiny of the various studies of programs and their efficacy. Some of the major differences between the programs included in this review revolved around the additional support offered to students, regardless of the model of acceleration implemented within the college. Some programs offered either compressed or redesigned pathways that allowed students to progress through the developmental mathematics sequence with greater speed but did not include any extra support for these students who are at higher risk of failure. Schools such as Santa Monica Community College and the community colleges within the CUNY system did not see great increases in their student success outcomes. The lack of a holistic student support model to compliment the acceleration resulted in minimal gains and lends overall credibility to the idea that developmental students have complex needs.

Other colleges changed the structure of their programs more dramatically and involved not only acceleration of some kind, but many support systems for the students to ensure that students are given the best chances at reaching their full potential and finding success in their college career. Schools such as Community College of Denver, Middle

Tennessee State University, and the Path2Stats course in California provided many resources for students such as mandatory tutoring and lab hours, student success courses, increased classroom time, more contextualized material, and holistic advising. The studies in this review showed greater student success levels given these additional resources and support the idea that developmental students need more than just acceleration in their programs, but support in cognitive and non-cognitive aspects of their college careers as well.

The field of developmental students is complex, and its problems cannot be addressed using simple solutions. The faculty in the classroom have a deep understanding of the complexity of the needs of their students and know that there is no one solution to the issues they face. A panacea of acceleration in developmental mathematics does not exist and each change to the courses available needs to be intentional and done with care for the students whose lives are directly affected. This review reveals that more research must be done in this area to identify the specific elements of these accelerated programs and combinations of these elements that lead to lasting and meaningful student success.

Acceleration is not a perfect solution to the difficulties facing developmental students and the faculty, staff, and administrations who serve them. There is room for great improvements within the field and acceleration shows promise to be a part of those improvements. As programs seek to increase their student success outcomes, acceleration can be included in these redesigns as part of a holistic approach to serve these high-risk student populations. Further research is needed to determine the role that acceleration should play in the future of developmental mathematics programs. The overarching goal of developmental education has always been to assist students in need of extra knowledge and support to be successful in their college-level courses and to give them the opportunities for an education and career. These same goals must be at the forefront of acceleration ideas and can guide the innovation process.

# CHAPTER III

## Research Method

Students who place into the lowest-level course of developmental mathematics in college are at the highest risk of not completing their developmental sequence and of attrition (Bailey et al., 2010). At the same time, they are also the students in need of the greatest levels of support and intervention to succeed in their coursework. The current trends of acceleration in developmental mathematics across the nation may positively affect some students, such as those who place into courses just below college-level gateway courses. However, the lowest-level placed students, and their college outcomes, must also be examined to reach an understanding of the relationship between the structure of a developmental mathematics program and the access, support, and opportunity it provides to the very students it proposes to serve. The purpose of this study was to examine the extent to which the number of courses required in a developmental mathematics sequence effected student success outcomes for students with the lowest levels of standardized placement exam scores. This study was guided by research questions regarding the completion of and grades in the first two courses in their developmental mathematics sequence.

### Positionality

Critical quantitative research involves a reflexive approach to the analysis of data and the communication of ideas and results. The use of a thorough examination of the researcher's paradigm or personal beliefs "will improve the ways in which we develop policies and services that assist all students in their access to and success in higher education" (Teranishi, 2007, p. 48). Ryan and Golden (2006) stated that "[i]f these issues are to be explored as part of quantitative methods they need to be included in the project protocol and research design from the outset" (p. 1198). Additionally, this is appropriate in research within higher education (Teranishi, 2007) and in research of any disadvantaged population (Griffiths, 2014). Indeed, "[s]uch a reflexive approach would not undermine the value of the research study but would add a depth of understanding about how, where, when and by whom data were collected" (Ryan & Golden, 2006, p. 1198). Finally, the inclusion of the following description of my personal beliefs demonstrates a change "from examining 'effects' of educational experiences to interrogating the ways these educational experiences are facilitated, how policies are created from higher education research, and the ways higher education researchers are studying educational practices" (Kilgo, 2016).

I have been an adjunct instructor in the Developmental Math department at UVU for the past nine years and I often have been assigned the courses that the full-time faculty do not want to teach. Mostly, this has been the lowest levels of courses that are offered. I have worked with these students one-on-one and hand-in-hand as they fight to overcome their disadvantages, gain an education, and become qualified for their desired work. I have seen their plight and it is near impossible to "unsee" it. I have a strong foundational belief in the underlying social justice purposes of developmental education. Developmental education is designed to provide opportunities for all students to achieve success, particularly those who are least prepared for college. Hardin (1998) states "[i]f we deny admission to students who are underprepared, we have narrowed our vision of the society we want to foster" (p. 23). Therefore, policies and reforms to colleges, and to developmental education programs in particular, must be carefully analyzed to ensure that they are assisting all students to attain success and not just creating opportunities for achievement gains among the better prepared students, while simultaneously hindering the success of less prepared students. I believe that society as a whole and developmental education programs specifically, are obligated to serve and support these students to the best of their abilities. However, I genuinely believe that I can maintain this belief as a fundamental part of my person, while still being open to the results of research and open to the voices and viewpoints of others around me.

Additionally, each institution of higher education and its accompanying students are unique. The needs of colleges, their faculty, and their students vary greatly and must be at the forefront of decision-making to best serve its students. Any changes to policies or programs must carefully consider the distinct needs and challenges that an institution's students face, and developmental mathematics is no exception. Much of the literature indicated that acceleration in developmental education is an experimental approach to developing alternative models of developmental programs in an effort to find a solution to low student success rates (Hagedorn & Kuznetsova, 2016; Kosiewicz et al., 2016; Martinez, 2018; Rutschow, 2019b; Scott-Clayton & Rodriguez, 2012). Some researchers suggest that academic momentum will result in higher success outcomes (Goldrick-Rab, 2007; Schudde & Keisler, 2019; Sommo & Ratledge, 2016), but more follow Scott-Clayton and Rodriguez's (2012) model of development, discouragement, or diversion functions of developmental education (Bailey et al., 2015; Clotfelter et al., 2015). The current literature showed varying degrees of success with this intervention (Bishop et al., 2018; Edgecombe, Jaggars, et al., 2013; Jaggars et al., 2015; Lucas & McCormick, 2007; Sheldon & Durdella, 2010), possibly related to the changes in student advising and other supplemental supports that some programs are implementing. However, I view the practice of acceleration in this field as reactionary instead of grounded in any sound learning theory. Legislators and administrators, frustrated with high costs and low success rates of developmental education, are pressuring leaders of developmental programs to reduce costs and increase completion rates. This pressure combined with abundant opportunities for funding of research that advocates for the implementation of these accelerated programs from various foundations, appears to be leading to an extreme push for the employment of accelerated programs across the country at community colleges and universities.

Much of the current literature and attitude about acceleration in developmental mathematics seems to encourage its implementation for all programs and all students. It appears that there are many in the field who feel that an increase in completion rates or success outcomes leads directly to the conclusion that the intervention is best for everyone involved. However, it is good to be skeptical of any “one-size-fits-all” approach or attitude to anything, let alone the education of students generally, or the underserved developmental student specifically. The desire to be inclusive and open to all ideas and to listen to all players who have an interest in the subject, especially students with the lowest levels of mathematical ability can only improve our decision making going forward.

My personal belief consists of a firm belief in the potential of all students. My work in developmental education is the result of the social justice underpinnings of these programs and my personal desire to provide opportunities for education. It is possible that this foundational credence affects my viewpoints and research and may lead to my rejection of or refusal to advocate for any system that improves overall success outcomes at the expense of those with lesser opportunities.

**Research Design**

Quantitative researchers begin with specific problems, which lead to questions that can be tested using a quantitative research design. The deductive nature of a quantitative approach to research allows the researcher to objectively analyze and uncover the predictability of certain outcomes based on developmental mathematics sequence length (Creswell, 2014). A positivist worldview of the issues of developmental mathematics and its contributions and pitfalls provides a starting point to “identify and assess the causes that influence outcomes” (Creswell, 2014, p. 7). Additionally, a transformative worldview of the issues of developmental mathematics and the student populations it serves “provides a voice” (Creswell, 2014, p. 10) for traditionally marginalized groups. These two worldviews held by me, the researcher, allow me to examine the relationships more fully between developmental mathematics programs and their structures for students who are at-risk and their associated educational success outcomes. Finally, the combination of worldviews, the available data, and the opportunity to explore and advance the understanding of the foundational mission of developmental education indicate that the quantitative approach was well-suited and an appropriate research design approach for this study.

In this study a quasi-experimental design was used “in which units are not assigned to conditions randomly” (Shadish et al., 2002, p. 14). The students were not randomly assigned to the different sequence lengths and the 4-course pre-reform sequence was no longer an option. Therefore, a quasi-experimental approach to this study allowed for the examination of a possible relationship between treatment and effect through the attentive consideration and reduction of alternative explanations, making it an appropriate design for this study. The participants of this study were students who enrolled in the lowest-level course of the pre-reform sequence in the developmental mathematics program and students who were enrolled in the lowest-level course of the post-reform sequence of the program. In the sample of the pre-reform course sequence, only students whose placement exam score would have placed them into the previous lowest-level course of the pre-reform sequence were included. The specific details of courses in these sequences, when they were offered, and their associated curriculums are discussed in the Participants and Sampling section of this document.

**Validity Threats**

As with all research, possible threats to validity may affect this study and its outcomes. Internal threats to validity included mortality, where "participants in an experiment sometimes fail to complete the outcome measures" (Shadish et al., 2002, p. 59), because some students may have dropped out of the developmental mathematics program making their outcomes unknown. There was also a historical internal threat to validity, which is "all events that occur between the beginning of the treatment and the posttest that could have produced the observed outcome in the absence of that treatment" (Shadish et al., 2002, p. 56). The two sequence lengths of developmental mathematics courses were not offered simultaneously, and the passage of time may have had some undue influence on the outcomes of this study. Additionally, confounding constructs, such as certain demographics or affective characteristics of both pre- and post-reform students, were present in this study, where "characteristics [which] were not part of the intended construct… but were nonetheless confounded with it in the study operations" (Shadish et al., 2002, p. 75). Furthermore, the program redesign in this institution has forced faculty to reevaluate their pedagogical approach and how they support their students as they move at a more accelerated pace through the mathematical concepts. This invigoration of teaching in the classroom was a possible internal threat to the validity of this study as an increase in completion rates may in part be the result of better teaching and support and not the course sequence length itself. This study must be repeated in the future when the new 2-course sequence becomes a more routine experience for both faculty and students.

A possible external threat to validity was the interaction of history and treatment. The post-reform developmental mathematics sequence had only been available for a short time frame. It was possible that the groups in this study were not representative of students who enroll in this university in the future. This program redesign must be evaluated regularly in the future to ensure the validity of the results of this study. Additionally, the interaction of the unique institutional setting and student population with the treatment means that the results of this study may not be generalizable to other populations of developmental mathematics students.

Furthermore, the Developmental Math department changed the standardized placement exam from the ACCUPLACER to the ALEKS during the time frame of this study. Although an ACT score was accepted throughout this time frame, this change in exams created a possible measurement validity threat. The ACCUPLACER exam was previously used to determine placement of students into developmental mathematics or college-level mathematics, before 2017. The Assessment Learning in Knowledge Spaces;

Preparation, Placement, and Learning exam (ALEKS) is the current exam used for student mathematics placement. Both exams are adaptive and adjust the difficulty level of each question given to the student based on the student's previous correct and incorrect responses. The decision to switch placement exams was based on the availability of scores from ALEKS for specific mathematical concepts and to use these scores to determine student placement more accurately. However, this feature of the ALEKS has not yet been utilized and a raw score is still used to determine placement into the developmental mathematics sequence or college-level mathematics. Furthermore, during the transition from the ACCUPLACER to the ALEKS exam, the institution accepted scores from either test, or an ACT Math score, as an acceptable placement exam. The faculty in the Developmental Math department determined an equivalency list of scores to determine the appropriate course placement into the developmental mathematics sequence regardless of the exam the student took, which is further explained in the research procedures section of this document. This study utilized this equivalency list of scores between the ACCUPLACER, ALEKS, and ACT Math to ensure mathematical ability-level equivalency in the sample selection of students. Students who enrolled into the lowest-level course of the pre-reform sequence and students with the same range of placement exam scores who placed into the lowest-level course of the post-reform sequence were selected for this study.

**Participants and Sampling**

Utah Valley University had over 42,000 students enrolled as of Fall 2019 and is projected to reach over 50,000 students before 2030 (UVU Student Enrollment Reports, n.d.). The sex of the student population that the university serves is 47% female and 53%

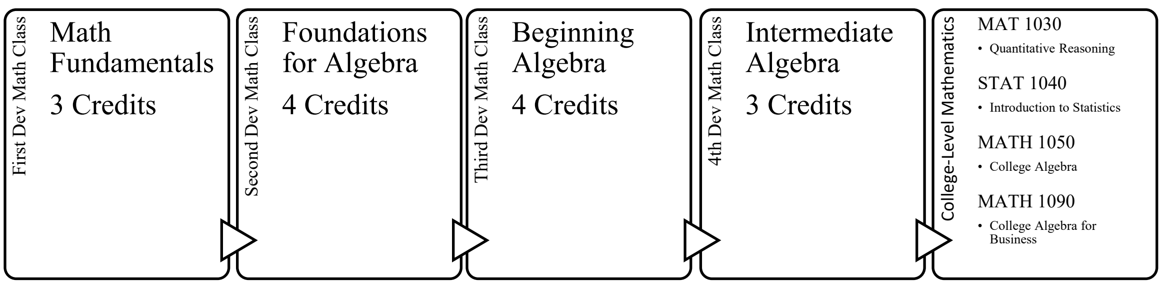
male, differing from national averages by ten percentage points (57% female; Snyder et al, 2019). The ethnicity of students is approximately 78% White, 11% Hispanic/Latino/a/x, and 1% each American Indian/Native Alaskan, Asian, Black, Native Hawaiian/Pacific Islander, and Unknown. Additionally, 77% of students are traditional students, defined as under 25 by UVU, and 23% are non-traditional students, 25 or older (UVU Student Characteristics, n.d.). Furthermore, as an open enrollment university, any student with a high school diploma or equivalency is accepted into the institution. Retention is a unique challenge for such open-access institutions and this university is no exception. The one-year retention rate is less than 60% (UVU Retention Rates, n.d.).

At UVU, approximately 60% of incoming freshman are placed into a developmental mathematics course. Of those placed into a developmental mathematics course, 54% are female and 46% are male. Of the developmental mathematics students, 74% are White and 26% are non-White. Most commonly, students were placed into courses that are one or two levels below college-level mathematics courses. Approximately 7% of all incoming students were placed into the pre-reform lowest-level developmental mathematics course. Of those placed into this lowest-level developmental mathematics course approximately 65% were White and 35% were non-White.

The Developmental Math department at this university has 21 full-time faculty with a varying number of adjuncts. Each fall and spring semester, approximately 100 sections are offered within the department, approximately 90 of which are below college-level mathematics, with fewer sections available over summer terms. In this department, there are nineteen full-time faculty and 43% of developmental mathematics sections are taught by adjuncts. A master's degree was required for adjuncts to teach the class just before college-level mathematics, in other words, the fourth and final course in the developmental mathematics sequence. In the developmental mathematics redesign, a master's degree is required to teach the second and final course in the developmental mathematics sequence. The Office of Teaching and Learning on campus provides optional professional development for all faculty, including adjuncts, on various topics, such as online instruction, curriculum development, and pedagogical techniques. The pre-reform developmental mathematics course sequence is shown in Figure 1.

**Figure 1**

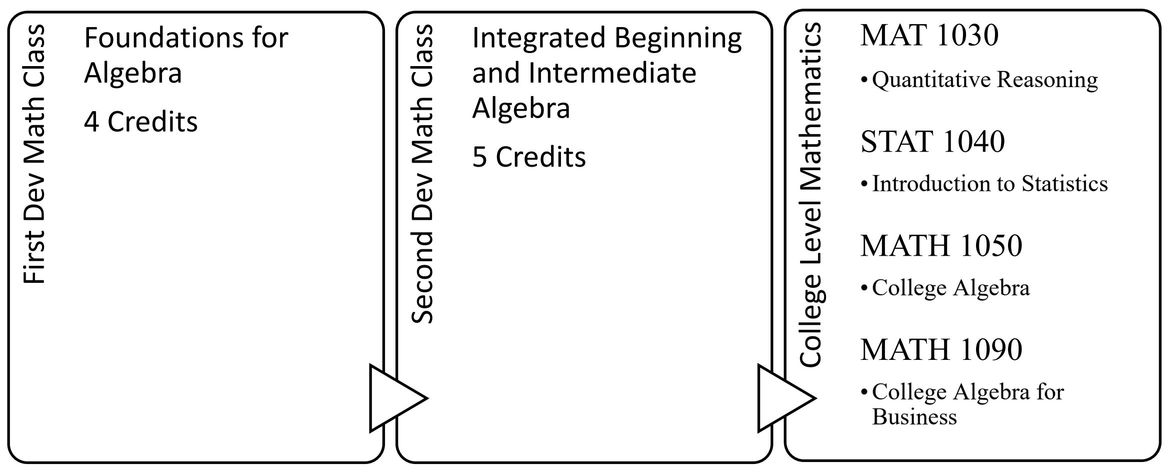
*Pre-Reform 4-Course Developmental Mathematics Sequence*




Prior to the redesign, the Developmental Math department offered four sequential courses to students, Math Fundamentals (3 credits), Foundations for Algebra (4 credits), Beginning Algebra (4 credits), and Intermediate Algebra (3 credits), as shown in Figure 1. The redesign of this sequence combined Math Fundamentals and Foundations for Algebra into a single 4-credit course now called Foundations for Algebra and combined Beginning Algebra and Intermediate Algebra into one five credit course, called Integrated Beginning and Intermediate Algebra, as shown in Figure 2. The curriculum for the two newly designed courses removed objectives that were repeated from one course to the next. The reformed curriculum also eliminated mathematical concepts that were not necessary for College Algebra readiness, such as complex fractions and composite functions. Primarily, the redesign necessitated that curriculum be covered at a much faster pace than previously required.

**Figure 2**

*Post-Reform 2-Course Developmental Mathematics Sequence*




Participants in this study were developmental mathematics students from Fall 2015 through Spring 2017 who enrolled in MAT 920, the lowest-level course offered of the pre-reform sequence (which best preliminary estimates are that this group includes approximately 1,300 students). Participants also included developmental mathematics students from Fall 2017 through Spring 2019 who would have been placed into the previous MAT 920 course, but were instead enrolled in MAT 950, the new lowest-level course offered in the post-reform sequence (which best preliminary estimates are that this group includes approximately 1,200 students).

**Data Source**

The data for this study came directly from the Institutional Research Office at UVU. Benefits to utilizing secondary internal data include the availability and accessibility of these data. Disadvantages include the self-reporting by students of ethnicity and sex, meaning there could be inaccuracies or patterns of missing data. There are benefits to utilizing this source of secondary internal data for this research. One benefit was the availability and accessibility of this data. Although there are not many disadvantages to internal secondary data, there were a couple in this instance.

The independent variables were a single predictor variable, sequence length, and control variables (number of attempts, sex, race, and age), which are similar to those used in other studies (Bahr, 2009; Crisp & Delgado, 2014; Fong et al., 2015; Sheldon & Durdella, 2010; Wolfle & Williams, 2014). The sex categories are male or female. Race categories are White and non-White. Age categories are traditional, defined as under the age of 25, and non-traditional, defined as 25 years or older. Placement exam scores were collected and sorted followed by matching using the equivalency chart provided by the Developmental Math department at UVU. This matching allowed for the formation of two groups of students. The first group consisted of those students whose placement exam scores placed them into the pre-reform lowest-level course. The second group consisted of students whose placement exams scores would have placed them into the pre-reform lowest-level course but were instead placed into the post-reform lowest-level. The first set of dependent variables are first and second class completion, which denote whether the students completed their first or second course in the sequence. The second set of dependent variables are the first and second class grade, which indicate the students' grades in the first or second lowest-level developmental mathematics class.

**Data and Variables**

Once data were collected from the Institutional Research Office at this university, it was appropriately sorted and cleaned in preparation for statistical analyses. The independent variables in this analysis were number of attempts, demographic variables, and course sequence length, described in Table 1. Dependent variables were the completion of and grades in developmental mathematics courses. First and second class completion are dichotomous variables and were coded as 0 or 1 (0 – class not completed, 1 – class completed). First and second class grade are continuous variables and were coded on the traditional GPA scale, 0.0 to 4.0.

**Table 1**

*Independent Variables*

| Variable Name | Coding | Definition |
|---|---|---|
| Sequence Length | 0 – pre-reform 4-course sequence, 1 – post-reform 2-course sequence | The form of developmental mathematics sequence into which the student was enrolled: post-reform or pre-reform. |
| Sex | 0 – male<br>1 – female | Student sex: male or female. |
| Race | 0 – non-White<br>1 – White | Student race: White or non-White |
| Age | 0 – non-traditional<br>1 – traditional | Traditional under 25 years old; or non-traditional, 25 years or older |
| Attempt | 0 – not first attempt<br>1 – first attempt | The first attempt of course or not first attempt |

**Research Procedures**

The procedures for this study were followed with great care on the part of the researcher. The researcher first obtained Internal Review Board (IRB) approval for the study from Utah Valley University, the data-providing institution, followed by IRB approval from Sam Houston State University (SHSU). The data collection began with a formal request to the Institutional Research Office at UVU. The data were internal secondary, student-level data for students enrolled into the lowest-level course of developmental mathematics from Fall 2015 through Spring 2019.

Once the data were received by the researcher, it was organized and examined for incorrect or missing data. The data were then sorted into pre-reform sequence and reformed sequence groups. At this point, the students in the sample who were placed into the lowest-level course of the post-reform sequence were sorted into two groups. The first group consisted of students with placement exam scores that would have placed them into the lowest-level course of the pre-reform course sequence. The second group consisted of students who would have been placed into the second to lowest-level course of the pre-reform course sequence. This study only examined the students in this first group whose placement exam score would have placed them into the previous lowest-level course of the pre-reform sequence.

Using the information in Table 3, the scores of students placed into the lowest-level developmental mathematics course post-reform (Foundations for Algebra) was examined to determine which students would have been placed into the lowest-level developmental mathematics course pre-reform (Math Fundamentals). Data screening was then completed by the researcher in Microsoft Excel and SPSS. This screening addressed issues of inaccurate or corrupt data as well as any missing data.

**Table 2**

*Placement Cut-Off Scores Pre- and Post-Reform*

| | ACCUPLACER | | ACT MATH | ALEKS |
|---|---|---|---|---|
| *Pre-Reform* | AA[a] | AL[b] | | |
| Math Fundamentals | 20 - 38 | -- | 0 - 5 | ≤ 14 |
| Foundations for Algebra | 39 - 65 | 25 - 39 | 6 - 13 | 15 - 16 |
| *Post-Reform* | AA | AL | | |
| Foundations for Algebra[c] | ≤ 65 | ≤ 39 | ≤ 16 | 0 - 18 |

[a]AA=Arithmetic. [b]AL=Algebra. [c]Students in the post-reform sequence that would have been placed in the pre-reform Foundations for Algebra were not included in this study.

Examination of the research questions was completed using regression, including a regression for continuous dependent variables and logistic regression for dichotomous dependent variables, using SPSS. Regression analysis is a statistical test used to determine the degree to which the dependent variable will change as a result of changes in the independent variable(s), while controlling for the effects of all other variables included in the regression model. Thus, regression was used to determine the extent to which the length of the developmental mathematics course sequence predicts students' completion of and grades in developmental mathematics courses.

**Data Analysis**

Data were collected from the Internal Research Office of UVU. The data included student enrollments into developmental mathematics courses for two different sequence lengths, student completion of and grades in these courses, along with basic demographic data. Sequence length and demographic factors were the independent variables and completion of and grades in developmental mathematics courses were the dependent variables. Regression and logistic regression approaches were used to determine if sequence length was a statistically significant predictor of grades in and completion of the first and second developmental mathematics courses, while controlling for sex, race, age, and the number times that course was attempted.

***Regression***

A traditional regression was conducted with continuous dependent variables to test the second and fourth research questions. Following the approach of Cohen et al. (2003), multicollinearity, homoscedasticity, distribution of errors, and linearity was examined to test the assumptions of regression. The predictor variables, sequence length, sex, age, and race, are all dichotomous variables. There must also be minimal multicollinearity among the independent variables. Visual inspection of scatter plots of residuals and predicted values allowed for the inspection of homoscedasticity. The Durbin-Watson test statistic was examined to confirm that residual terms were uncorrelated. Histograms with a normal overlay were examined to confirm that residuals were normally distributed with a mean of 0. Finally, the relationship between the independent and dependent variables was found to be linear. A correlation table for all variables was provided. Means and standard deviations by groups were also reported. A regression was then conducted for the continuous outcome variables which included grades in the first and second developmental mathematics classes. The equation built using a standardized beta coefficients model follows.

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon_1$$

In this model, $X_1$ is the sequence length, two or four courses; $X_2$ is sex, male or female; $X_3$ is race, White and non-White; $X_4$ is age, traditional or non-traditional; and $X_5$ is attempt, first attempt, or not first attempt. The strength of each predictor variable, while holding other predictors constant, on the dependent variables was expressed using standardized beta coefficients. The beta weights and bivariate correlations of each predictor variable on $Y$ was examined to determine the level of influence each independent variable has on the outcome. The adjusted $R^2$ was used to determine goodness-of-fit and model variance.

***Binary Logistic Regression***

Binary logistic regression was conducted to test the research questions with dichotomous outcome variables: completion of first and second developmental mathematics courses, testing the first and third research questions. Following the approach of Cohen et al. (2003), issues of linearity to the log odds, multicollinearity, and correct model specification were addressed to meet the assumptions of logistic regression. The relationship between each independent variable and the log odds of the dependent variable should be linear. Multicollinearity was checked by running a linear regression and Tolerance and VIF were also checked. Descriptive statistics were provided. A correlation matrix was presented in a table and described.

A binary logistic regression was then conducted for each dichotomous outcome variable, that is, completion of the first and second developmental mathematics classes. A logistic regression predicts the probability of the outcome, or dependent variable, given that the predictor variables, or independent variables have already happened (Cohen et al., 2003). The equation built using a standardized beta coefficients model for logistic regression follows.

$$P(Y) = \frac{1}{1 + e^{-(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5)}}$$

In this model, $X_1$ is the sequence length, two or four courses; $X_2$ is sex, male or female; $X_3$ is race, White and non-White; $X_4$ is age, traditional or non-traditional; and $X_5$ is the number of attempts, first attempt or not first attempt. The goodness-of-fit of this model was determined by using the log-likelihood or deviance of the model along with a pseudo $R^2$ statistic. To understand the individual contributions of each independent variable, the beta coefficients were examined. The odds ratios, or *Exp(B)*, along with confidence intervals; and log odds, along with standard error are given.

**Ethical Considerations and Plans for Presenting Results**

The main ethical concerns of this study come with the presentation and distribution of the outcomes of this study. The accelerated developmental mathematics program at this university is unique in its design and implementation. Different institutions have varying cultures, student demographics, and faculty styles. This exact accelerated approach to developmental mathematics may not be appropriate for all settings and each program or institution must make choices based on their circumstances and student needs. It is possible that the tone or approach to the presentation of the results of this study could be strategically used to convince audiences of the superiority of one type of redesign in developmental education over another. The university used in this study has unique student population demographics and the generalizability of the results of this study is limited in nature. Therefore, the researcher maintained a neutral tone in the discussion of the results of this study and did not purposely try to advance any educational approach or agenda.

Additionally, it is possible that a statistically significant relationship between course sequence length and completion of mathematics courses may not be strong enough to justify a full redesign by an institution that is managing thousands of students and faculty. The practical value and importance of the results should be determined by individual institutions. For example, even a very weak relationship between course sequence length and student outcomes may be meaningful if the institution is able to get students through their mathematical studies in less calendar time (Saxon & Martirosyan, 2017).

**Summary**

Many colleges around the country have implemented reform by using acceleration models for developmental mathematics sequences. More research must be done to study the resurgence of acceleration in developmental mathematics and its corresponding student success outcomes to truly uncover the characteristics or combinations of characteristics that contribute to a successful program. This is especially important as very few studies about acceleration in developmental mathematics have focused on the students placed into the lowest-level course. Any changes to developmental mathematics programs must be carefully considered and intentionally implemented in ways that work for the benefit of all students. Students who require the most assistance to reach the level of college-readiness are the very students that developmental education is designed to support. This study furthers understanding in the field of developmental mathematics on course sequence lengths and their effect on the success of the most vulnerable students.

# CHAPTER IV

## Results

The purpose of this study was to examine the extent to which the number of courses required in a developmental mathematics sequence effected student success outcomes for students with the lowest levels of standardized placement exam scores. Binary logistic regression was conducted to predict students' completion of developmental mathematics courses for students in the pre-reform 4-course sequence and students in the post-reform 2-course sequence while controlling for age, sex, race, and attempt number. Although it was planned to use regression to predict students' GPA in their first and second course while controlling for age, sex, race, and attempt number, the GPA scores did not meet the normality requirements. Instead, a chi-squared test of association was conducted to examine the relationship between the two different sequence lengths and the pass/fail rates in these same courses. UVU provided the data for this study by making available to the researcher the placement exam scores, courses, and final grades for students first enrollment in the lowest levels and subsequent course enrollments in and grades in developmental mathematics.

### Factor and Demographic Analyses

The data cleaning and sorting process involved several steps. All placement exam scores that UVU had on record for each student was provided and all but the most recent score prior to enrolling in the lowest-level course of developmental mathematics were included. Students in the post-reform group who enrolled in the lowest-level course (MAT950) whose placement exam scores would have placed them into the pre-reform lowest level course (MAT920) were identified and included. In total, this resulted in 1,899 students in the sample.

There were students from this group who were not included in the final study. Students who enrolled in MAT920 prior to the reform, but whose placement exam scores placed them into a higher course were not included ($n$ = 71). Students may have multiple reasons for enrolling in a course that was lower than the course their placement exam directed them to, including personal time commitments, confidence levels, and advice of advisers. Students who were missing a placement exam score ($n$ = 68); students who took MAT950, did not pass, and then enrolled in MAT920 ($n$ = 4); students who enrolled in MAT920 and MAT950 concurrently ($n$ = 3); and students who were missing a final grade for the course ($n$ = 2) were also excluded. Finally, the students who enrolled in pre-reform lowest-level course, but subsequently enrolled in the post-reform lowest-level course were also excluded ($n$ = 107), however descriptive statistics for this group are provided later in this chapter. The remaining sample of 1,644 students were those with the lowest levels of placement exam scores, who enrolled into the lowest-level course in which they were placed as their first mathematics course at the institution, and who had a recorded final grade in their courses.

Although UVU has less than 1% of students with unidentified ethnicity, approximately 20% of developmental mathematics students had not identified their ethnicity ($N$ = 329). As developmental students were a substantial portion of the students in this study, two regression analyses were performed, one including race as a variable, and one without race. The discrepancy between the university student population and the developmental mathematics student population who self-identified their ethnicity should be further examined in a future study. The final sample for this study consisted of two groups: those who identified their ethnicity (*N* = 1,315) and those who did not (*N* = 329). Both groups were analyzed for each of the research questions of this study and the sample size for this study, by nature of the chronological order of research questions, decreased with each analysis. Table 3 shows the descriptive statistics for both groups included in this study, comparing pre-reform and post-reform students.

**Table 3**

*Descriptive Statistics of Students by Pre- and Post-Reform*

| | Total | | Pre-Reform | | Post-Reform | |
|---|---|---|---|---|---|---|
| | Identified Ethnicity | | | | | |
| Characteristic | *N* = 1,315 | | *n* = 743 | | *n* = 572 | |
| Age (average) | *M* = 23.37 | | *M* = 22.95 | | *M* = 23.91 | |
| | *SD* = 6.18 | | *SD* = 6.10 | | *SD* = 6.25 | |
| Age Coded *n* (%) | | | | | | |
| Traditional | 981 | (75) | 587 | (79) | 394 | (69) |
| Non-Traditional | 334 | (25) | 156 | (21) | 178 | (31) |
| Sex *n* (%) | | | | | | |
| Female | 680 | (52) | 388 | (52) | 292 | (51) |
| Male | 635 | (48) | 355 | (48) | 280 | (49) |
| Ethnicity *n* (%) | | | | | | |
| White | 865 | (66) | 471 | (63) | 394 | (69) |
| Hispanic/Latino/a/x | 265 | (20) | 163 | (22) | 102 | (18) |
| American Indian/ Native Alaskan | 21 | (2) | 14 | (2) | 7 | (1) |
| Black | 81 | (6) | 45 | (6) | 36 | (6) |
| Asian | 45 | (3) | 24 | (3) | 21 | (4) |
| Native Hawaiian/ Pacific Islander | 38 | (3) | 26 | (4) | 12 | (2) |
| Race Coded *n* (%) | | | | | | |
| White | 865 | (66) | 471 | (63) | 394 | (69) |

(continued)

| | Total | | Pre-Reform | | Post-Reform | |
|---|---|---|---|---|---|---|
| | Identified Ethnicity | | | | | |
| Characteristic | *N* = 1,315 | | *n* = 743 | | *n* = 572 | |
| Non-White | 450 | (34) | 272 | (37) | 178 | (31) |
| | Unidentified Ethnicity | | | | | |
| Characteristic | *N* = 329 | | *n* = 202 | | *n* = 127 | |
| Age (average) | *M* = 23.03 | | *M* = 23.08 | | *M* = 22.95 | |
| | *SD* = 6.28 | | *SD* = 6.47 | | *SD* = 5.10 | |
| Age Coded *n* (%) | | | | | | |
| Traditional | 256 | (78) | 154 | (76) | 102 | (80) |
| Non-Traditional | 73 | (22) | 48 | (24) | 25 | (20) |
| Sex *n* (%) | | | | | | |
| Female | 153 | (47) | 96 | (48) | 57 | (45) |
| Male | 176 | (53) | 106 | (52) | 70 | (55) |

**Research Question 1**

A binary logistic regression was used to address the extent to which age, sex, race, and sequence length predicted whether a student with the lowest-level placement exam scores completed their first course. The sample for this analysis was the entire sample described in Table 3. The dependent variable was completion of the first class (completed first class = 1, did not complete first class = 0). The independent variables used were age (traditional = 1, non-traditional = 0), sex (female = 1, male = 0), race (White = 1, non-White = 0), and sequence length (post-reform 2-course = 1, pre-reform 4-course = 0). The sample for this question included all students with an identified ethnicity in the original sample ($N$ = 1,315). This analysis, shown in Table 4, did not result in a statistically significant model, $\chi^2(4, N = 1{,}315) = 7.14$, $p = .13$. A similar binary logistic regression was performed for students with an unidentified ethnicity, using age, sex, and sequence length as predictor variables for completion of their first course.

This analysis, also shown in Table 4, was not statistically significant, $\chi^2$ (3, $N$ = 329) = 2.11, $p$ = .55.

**Table 4**

*Binary Logistic Regression Coefficients of Age, Sex, Race, and Sequence Length on First Developmental Mathematics Course Completion*

| Variable | $B$ | $SE$ | $OR$ | 95% CI | Wald Statistic | $p$ |
|---|---|---|---|---|---|---|
| Identified Ethnicity ($N$ = 1,315) | | | | | | |
| Age[a] | 0.38 | 0.20 | 1.47 | [0.99, 2.18] | 3.55 | .06 |
| Sex[b] | –0.16 | 0.19 | 0.85 | [0.59, 1.23] | 0.75 | .39 |
| Race[c] | 0.12 | 0.19 | 1.13 | [0.77, 1.64] | 0.39 | .54 |
| Sequence Length[d] | 0.34 | 0.19 | 1.40 | [0.96, 2.05] | 3.07 | .08 |
| Unidentified Ethnicity ($N$ = 329) | | | | | | |
| Age[a] | 0.01 | 0.35 | 1.01 | [0.51, 2.00] | <0.01 | .98 |
| Sex[b] | 0.18 | 0.29 | 1.20 | [0.67, 2.13] | 0.37 | .54 |
| Sequence Length[d] | 0.41 | 0.31 | 1.50 | [0.82, 2.76] | 1.72 | .19 |

*Note.* CI = confidence interval for odds ratio ($OR$).

[a] 0 = non-traditional age and 1 = traditional age. [b] 0 = male and 1 = female. [c] 0 = non-White and 1 = White. [d] 0 = 4-course sequence and 1 = 2-course sequence.

**Research Question 2**

In the original proposal for this study, the researcher planned to conduct a regression to find the extent to which age, sex, race, and sequence length predicted a student's GPA in their first course. However, the histogram of GPA in the first class was inspected and found to violate normality. Other tests of normality, including the Kolmogorov-Smirnov test and Shapiro-Wilk test, failed and the Q-Q plot was observed to have a clear S-shape. Therefore, this research question was adjusted to use a chi-squared test of association to determine the extent to which there was a relationship between age, sex, race, and sequence length with whether a student passed or failed their first course. The first course in both the pre-reform and post-reform sequences required a C-, or GPA of 1.7, to move on to the subsequent course. Additionally, students who earned a grade of UW (unofficial withdrawal) were marked as having failed the course, as a UW counts as a 0.0 GPA on the student's transcript. The results of the chi-squared tests are shown in Table 5 for students with both an identified and unidentified ethnicity. For students with an identified ethnicity, race was the only statistically significant relationship with Whites associated with an increased passing rate, $\chi^2(1) = 9.52$, $p < .01$, however the effect size was small ($\phi = .09$). For students with an unidentified ethnicity, age was the only variable with a statistically significant relationship with traditional-aged students having lower rates of passing their first course, $\chi^2(1) = 4.76$, $p = .03$, however its effect size was also fairly small ($\phi = .13$).

**Table 5**

*Frequencies and Chi-Squared Results for Pass/Fail in First Course*

| Variable | Pass | Fail | $\chi^2$ | $\phi$ |
|---|---|---|---|---|
| | *n* (%) | *n* (%) | | |
| Identified Ethnicity (*N* = 1,247) | | | | |
| Age[a] | | | | |
| Traditional | 652 (74) | 281 (78) | 2.81 | –.05 |
| Non-Traditional | 235 (26) | 79 (22) | | |
| Sex[b] | | | | |
| Female | 464 (52) | 176 (49) | 1.20 | .03 |
| Male | 423 (48) | 184 (51) | | |
| Race[c] | | | | |
| White | 606 (68) | 213 (59) | 9.59** | .09 |
| Non-White | 281 (32) | 147 (41) | | |
| Sequence Length[d] | | | | |

(continued)

| Variable | Pass | Fail | $\chi^2$ | $\phi$ |
|---|---|---|---|---|
| | *n* (%) | *n* (%) | | |
| Post-Reform 4-course | 395 (45) | 151 (42) | 0.70 | .02 |
| Pre-Reform 2-course | 492 (55) | 209 (58) | | |
| Unidentified Ethnicity ($N = 305$) | | | | |
| Age[a] | | | | |
| Traditional | 137 (75) | 104 (85) | 4.76* | –.13 |
| Non-Traditional | 46 (25) | 18 (15) | | |
| Sex[b] | | | | |
| Female | 88 (48) | 53 (43) | 0.64 | .05 |
| Male | 95 (52) | 69 (57) | | |
| Sequence Length[d] | | | | |
| Post-Reform 4-course | 72 (39) | 45 (37) | 0.19 | .03 |
| Pre-Reform 2-course | 111 (61) | 77 (63) | | |

*Note*. This sample included only students whose final grade in the course counted toward their overall GPA. A final grade of W (withdrawal) did not count toward GPA scores.

[a] 0 = non-traditional age and 1 = traditional age. [b] 0 = male and 1 = female. [c] 0 = non-White and 1 = White. [d] 0 = 4-course sequence and 1 = 2-course sequence.

*$p < .05$, **$p < .01$.

**Research Question 3**

A binary logistic regression was used to address the extent to which age, sex, race, attempt number, and sequence length predicted whether a student with the lowest-level placement exam scores completed their second course. The sample for this analysis included all students in the original sample who enrolled into a second course during the time frame of the given study ($N = 425$) and is described in the first part of Table 6.

**Table 6**

*Descriptive Statistics for Lowest-Level Mathematics Students Who Enrolled in a Second Course by Pre- and Post-Reform*

| Characteristic | Total | | Pre-Reform | | Post-Reform | |
|---|---|---|---|---|---|---|
| | *N* | (%) | *n* | (%) | *n* | (%) |
| Identified Ethnicity (*N* = 425) | | | | | | |
| Age | | | | | | |
| Traditional | 319 | (75) | 245 | (80) | 74 | (63) |
| Non-Traditional | 106 | (25) | 62 | (20) | 44 | (37) |
| Sex | | | | | | |
| Female | 214 | (50) | 156 | (51) | 58 | (49) |
| Male | 211 | (50) | 151 | (49) | 60 | (51) |
| Race | | | | | | |
| White | 264 | (62) | 188 | (61) | 76 | (64) |
| Non-White | 161 | (38) | 119 | (39) | 42 | (36) |
| Attempt | | | | | | |
| First Attempt | 336 | (79) | 257 | (84) | 79 | (67) |
| Not First Attempt | 89 | (21) | 50 | (16) | 39 | (33) |
| Unidentified Ethnicity (*N* = 93) | | | | | | |
| Age | | | | | | |
| Traditional | 74 | (80) | 49 | (77) | 25 | (86) |
| Non-Traditional | 19 | (20) | 15 | (23) | 4 | (14) |
| Sex | | | | | | |
| Female | 49 | (53) | 32 | (50) | 17 | (59) |
| Male | 44 | (47) | 32 | (40) | 12 | (41) |
| Attempt | | | | | | |
| First Attempt | 68 | (73) | 51 | (80) | 17 | (59) |
| Not First Attempt | 25 | (27) | 13 | (20) | 12 | (41) |

*Note.* Sample included only students who enrolled in a second developmental mathematics course.

The dependent variable for the students with an identified ethnicity was completion of the second class (completed first class = 1, did not complete first class = 0). The independent variables used were age (traditional = 1, non-traditional = 0), sex (female = 1, male = 0), race (White = 1, non-White = 0), attempt (first attempt = 1, not first attempt = 0) and sequence length (post-reform 2-course = 1, pre-reform 4-course = 0). The analysis resulted in a statistically significant model, $\chi^2(5, N = 425) = 23.71, p < .01$. The Cox and Snell pseudo $R^2$ was .054 and the Nagelkerke pseudo $R^2$ was .102, indicating that the model did not account for a large portion of the variance. The model showed an overall correct prediction rate of 87.3%. Table 7 shows the regression coefficients, standard errors, Wald test, and odds ratios with 95% confidence intervals.

The Wald test indicated that race and attempt were statistically significant predictors of completion of the second course ($p < .05$ and $p < .01$, respectively). Students who were taking the course for the first time had more than twice the odds to complete their second class, (*OR* = 2.21) than students who were retaking the course, adjusting for age, sex, race, and sequence length. However, the confidence interval for this odds ratio was quite broad, 95% CI [1.13, 4.30], indicating a relatively imprecise odds ratio. Additionally, non-Whites had 2.73 times the odds of completing their second class in comparison to Whites when the other predictor variables are held constant, but the confidence interval indicated it may be as small as 1.34 times the odds, *OR* = 2.73, 95% CI [1.34, 5.56].

Another binary logistic regression was completed for students with an unidentified ethnicity to determine the extent to which age, sex, attempt, and sequence length predicted completion in the second course. The sample for this question included all students with an unidentified ethnicity who enrolled in a second course ($N = 93$). This analysis also resulted in a statistically significant model, $\chi^2(4, N = 93) = 9.52, p < .05$. The Cox and Snell pseudo $R^2$ was .097 and the Nagelkerke pseudo $R^2$ was .181, indicating that the model did not account for a large portion of the variance. The model showed an overall correct prediction rate of 87.1%. Table 7 shows the regression coefficients, standard errors, Wald test, and odds ratios with 95% confidence intervals. The Wald test indicated that sequence length was the only statistically significant predictor of completion of the second course ($p < .05$). Students in the pre-reform 4-course sequence had 5.49 times the odds of completing their second course, $OR = 5.49$, 95% CI [1.41, 21.74], than students in the post-reform 2-course sequence. But, again, the odds ratio was quite broad, indicating that students in the 4-course sequence may have had as little as 1.41 times the odds of completing their second course as students in the 2-course sequence.

**Table 7**

*Regression Coefficients of Lowest-Level Mathematics Student Characteristics and Sequence Length on Completion of Second Course*

| Variable | *B* | *SE* | *OR* | 95% CI | Wald Statistic | *p* |
|---|---|---|---|---|---|---|
| Identified Ethnicity ($N = 425$) | | | | | | |
| Age[a] | 0.59 | 0.33 | 1.81 | [0.95, 3.43] | 3.28 | .07 |
| Sex[b] | –0.04 | 0.30 | 0.96 | [0.53, 1.75] | 0.01 | .91 |
| Race[c] | –1.01 | 0.36 | 0.37** | [0.18, 0.74] | 7.72 | .01 |
| Attempt[d] | 0.79 | 0.43 | 2.21* | [1.13, 4.30] | 5.38 | .02 |
| Sequence Length[e] | –0.61 | 0.32 | 0.54 | [0.29, 1.10] | 3.68 | .06 |
| Unidentified Ethnicity ($N = 93$) | | | | | | |
| Age[a] | 0.03 | 0.89 | 1.03 | [0.18, 5.94] | 0.00 | .97 |
| Sex[b] | –0.17 | 0.68 | 0.84 | [0.22, 3.18] | 0.06 | .80 |

(continued)

| Variable | $B$ | $SE$ | $OR$ | 95% CI | Wald Statistic | $p$ |
|---|---|---|---|---|---|---|
| Attempt[d] | –2.01 | 1.12 | 0.13 | [0.01, 1.15] | 3.37 | .07 |
| Sequence Length[e] | –1.71 | 0.70 | 0.18* | [0.05, 0.71] | 6.00 | .01 |

*Note.* CI = confidence interval for odds ratio (*OR*).

[a] 0 = non-traditional age and 1 = traditional age. [b] 0 = male and 1 = female. [c] 0 = non-White and 1 = White. [d] 0 = not first attempt and 1 = first attempt. [e] 0 = 4-course sequence and 1 = 2-course sequence.

$^{*}p < .05$. $^{**}p < .01$.

**Research Question 4**

In the original proposal for this study, the researcher planned to conduct a regression to find the extent to which age, sex, race, attempt, and sequence length predicted a student's GPA in their second course. However, similarly to GPA in the first course, the histogram of GPA in the second class was inspected and also found to violate normality. Other tests of normality including the Kolmogorov-Smirnov test and Shapiro-Wilk test failed and the Q-Q plot was observed to have a clear S-shape. Therefore, this research question was adjusted to use a chi-squared test of association to determine the extent to which there was a relationship between age, sex, race, attempt, and sequence length with whether a student passed or failed their second course. All courses in the developmental mathematics sequence, both pre- and post-reform, required a grade of C-, or 1.7 GPA, to move on to the subsequent course except for the final course in the sequence, which required a grade of C, or 2.0 GPA to move on to a college-level mathematics course. Students were coded with a passing grade if they met the minimum grade requirement for their specific second developmental mathematics class.

Additionally, students who earned a grade of UW (unofficial withdrawal) were marked as having failed the course, as a UW counts as a 0.0 GPA on the student's transcript. The results of the chi-squared tests are shown in Table 8 for students with both an identified and unidentified ethnicity. For students with an identified ethnicity, attempt and sequence length were the only variables with a statistically significant relationship with passing or failing the second developmental mathematics course. Students who were attempting their second course for the first time experienced higher rates of passing their second course than those on their second or greater attempt at that course, $\chi^2(1) = 13.69$, $p < .01$, however the effect size was fairly small ($\phi = .19$). In addition, students in the post-reform 2-course sequence experienced lower rates of passing their second developmental mathematics course, $\chi^2(1) = 66.28$ $p < .01$,with a moderately strong effect size ($\phi = -.41$). For students with an unidentified ethnicity, sequence length was the only variable with a statistically significant relationship to whether a student passed or failed their second course with lower rates of passing for students in the post-reform 2-course sequence, $\chi^2(1) = 8.57$, $p < .01$, with a moderate effect size ($\phi = -.31$).

**Table 8**

*Frequencies and Chi-Squared Results for Pass/Fail in Second Course*

| Variable | Pass | Fail | $\chi^2$ | $\phi$ |
|---|---|---|---|---|
| | *n* (%) | *n* (%) | | |
| | Identified Ethnicity (*N* = 395) | | | |
| Age | | | | |
| Traditional | 179 (77) | 120 (73) | 0.65 | .04 |
| Non-Traditional | 53 (23) | 43 (26) | | |
| Sex | | | | |
| Female | 114 (49) | 83 (51) | 0.12 | –.02 |
| Male | 118 (51) | 80 (49) | | |

(continued)

| Variable | Pass | Fail | $\chi^2$ | $\phi$ |
|---|---|---|---|---|
| | *n* (%) | *n* (%) | | |
| Race | | | | |
| White | 142 (61) | 97 (60) | 0.16 | .02 |
| Non-White | 90 (39) | 66 (40) | | |
| Attempt | | | | |
| First Attempt | 198 (85) | 114 (70) | 13.69** | .19 |
| Not First Attempt | 34 (15) | 49 (30) | | |
| Sequence Length | | | | |
| Post-Reform 4-course | 26 (11) | 78 (48) | 66.28** | –.41 |
| Pre-Reform 2-course | 206 (89) | 85 (52) | | |
| Unidentified Ethnicity ($N$ = 89) | | | | |
| Age | | | | |
| Traditional | 35 (80) | 37 (82) | 0.10 | –.03 |
| Non-Traditional | 9 (20) | 8 (18) | | |
| Sex | | | | |
| Female | 23 (52) | 23 (51) | 0.01 | .01 |
| Male | 21 (48) | 22 (49) | | |
| Attempt | | | | |
| First Attempt | 32 (73) | 32 (71) | 0.03 | .02 |
| Not First Attempt | 12 (27) | 13 (29) | | |
| Sequence Length | | | | |
| Post-Reform 4-course | 7 (16) | 20 (44) | 8.57** | –.31 |
| Pre-Reform 2-course | 37 (84) | 25 (56) | | |

*Note.* This sample included only students whose final grade in the course counted toward their overall GPA. A final grade of W (withdrawal) did not count toward GPA scores.

[a] 0 = non-traditional age and 1 = traditional age. [b] 0 = male and 1 = female. [c] 0 = non-White and 1 = White. [d] 0 = 4-course sequence and 1 = 2-course sequence.

*$p$ < .05. **$p$ < .01.

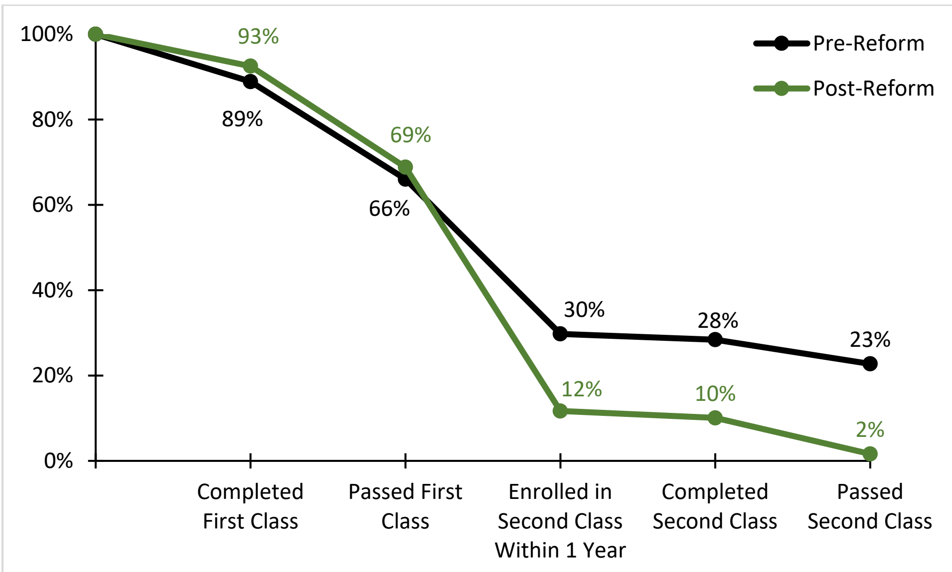
**Additional Analyses**

As expected, there was a high number of students who, even though they passed their first course, did not re-enroll in the subsequent developmental mathematics course in their assigned sequence. However, the available data revealed that number to be higher for students in the post-reform 2-course sequence than for students in the pre-reform 4-course sequence, prompting further exploration of the data. A descriptive analysis for both identified and unidentified ethnicity students, shown in Figures 3, 4, 5, and 6 which followed the progression of students through their first two developmental mathematics courses, uncovers the differences of enrollment in a second course between the pre- and post-reform sequence lengths. These differences led to additional statistical analysis that, although unplanned at the beginning of this study, are now included.

The data gathered for this study were limited in time frame, and as such, students with an identified ethnicity for whom data one year ($N$ = 1,047), and two years ($N$ = 838) were available were the subject of continued analyses. Similarly, students with an unidentified ethnicity for whom data one year ($N$ = 259), and two years ($N$ = 223) were also examined. Students who enrolled in the subsequent course after passing their first course within two semesters were considered having enrolled in the subsequent course within one year. Figure 3 shows the progression of pre- and post-reform students whose ethnicity was identified and for whom one year of data after taking their first course were available, from completing, and passing their first course, to enrolling in, completing, and passing their second course. In the pre-reform 4-sequence course, 66% of students passed their first course, and 30% enrolled in the subsequent course within one year. In the post-reform 2-course sequence, 69% passed their first course, but only 12% enrolled in the subsequent course within one year.

**Figure 3**

*Progression of Students with Lowest Placement Scores and an Identified Ethnicity for Whom One Year of Data Following the First Class were Available*

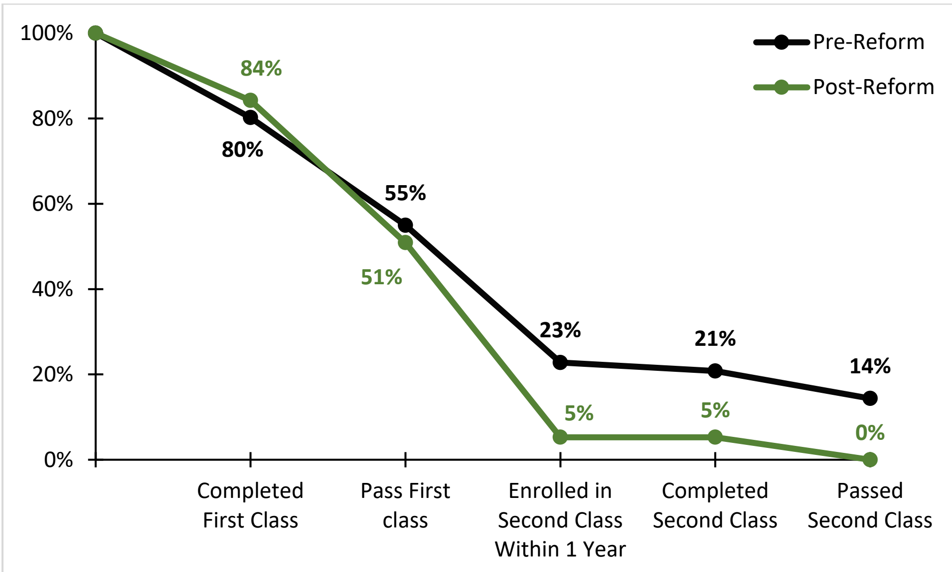



*Note.* Pre-reform $N = 739$. Post-reform $N = 308$.

Figure 4 shows the progression of pre- and post-reform students whose ethnicity was not identified and for whom one year of data after taking their first course were available, from completing, and passing their first course, to enrolling in, completing, and passing their second course. In the pre-reform 4-sequence course, 55% of students passed their first course, and 23% enrolled in the subsequent course within one year. In the post-reform 2-course sequence, 51% passed their first course, but only 5% enrolled in the subsequent course within one year.

**Figure 4**

*Progression of Students with Lowest Placement Scores and an Unidentified Ethnicity for Whom One Year of Data Following the First Class were Available*

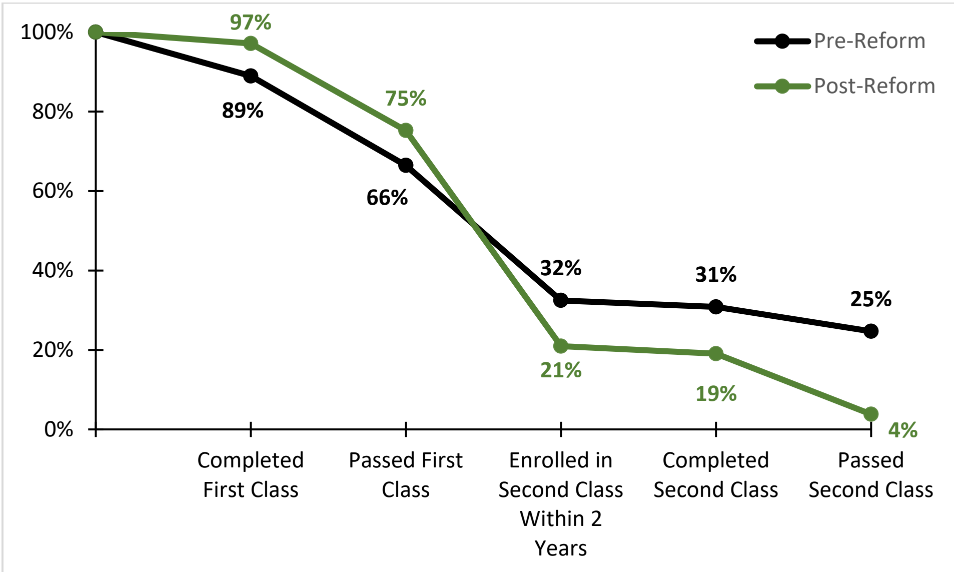



*Note.* Pre-reform $N = 202$. Post-reform $N = 57$.

Students who enrolled in the subsequent course after passing their first course within four semesters were considered having enrolled in the subsequent course within two years. Figure 5 shows the progression of pre- and post-reform students with an identified ethnicity and for whom two years of data after taking their first course were available, from completing, and passing their first course, to enrolling in, completing, and passing their second course. In the pre-reform 4-sequence course, 66% of students passed their first course, and 32% enrolled in the subsequent course within one year. In the post-reform 2-course sequence, 75% passed their first course, but only 21% enrolled in the subsequent course within one year.

**Figure 5**

*Progression of Students with Lowest Placement Scores and an Identified Ethnicity for Whom Two Years of Data Following the First Class were Available*

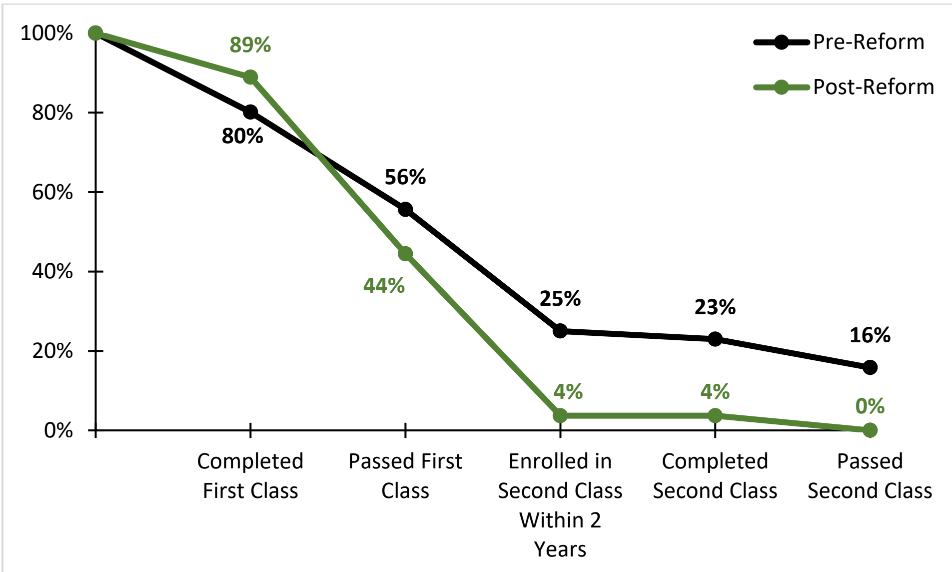



*Note.* Pre-reform $N = 733$. Post-reform $N = 105$.

Figure 6 shows the progression of pre- and post-reform students with an unidentified ethnicity for whom two years of data after taking their first course were available, from completing, and passing their first course, to enrolling in, completing, and passing their second course. In the pre-reform 4-sequence course, 56% of students passed their first course, and 25% enrolled in the subsequent course within one year. In the post-reform 2 -course sequence, 44% passed their first course, but only 4% enrolled in the subsequent course within one year. The difference in these percentages of students who re-enroll in the following course after passing the first course led to further investigation through statistical analyses to further explore these results.

**Figure 6**

*Progression of Students with Lowest Placement Scores and an Unidentified Ethnicity for Whom Two Years of Data Following the First Class were Available*




*Note.* Pre-reform $N = 196$. Post-reform $N = 27$.

***Re-Enrollment Within One Year***

A binary logistic regression was used to address the extent to which age, sex, and race predicted whether a student with the lowest-level placement score and who passed their first course would enroll in their second course within one year. The sample for this question included all students who earned a passing grade in their first course and for whom one year of data were available ($N = 700$) and is described in the first part of Table 9.

**Table 9**

*Descriptive Statistics for Students with an Identified Ethnicity by Pre- and Post-Reform for all Students for Whom One Year of Data were Available*

| Characteristic | Total | | Pre-Reform | | Post-Reform | |
|---|---|---|---|---|---|---|
| | *N* (%) | | *n* (%) | | *n* (%) | |
| Identified Ethnicity (*N* = 700) | | | | | | |
| Age | | | | | | |
| Traditional | 521 | (74) | 381 | (78) | 140 | (66) |
| Non-Traditional | 179 | (26) | 107 | (22) | 72 | (34) |
| Sex | | | | | | |
| Female | 370 | (53) | 254 | (52) | 116 | (55) |
| Male | 330 | (47) | 234 | (48) | 96 | (45) |
| Race | | | | | | |
| White | 478 | (68) | 324 | (66) | 154 | (73) |
| Non-White | 222 | (32) | 164 | (34) | 58 | (27) |
| Unidentified Ethnicity (*N* = 140) | | | | | | |
| Age | | | | | | |
| Traditional | 101 | (72) | 78 | (70) | 23 | (79) |
| Non-Traditional | 39 | (28) | 33 | (30) | 6 | (21) |
| Sex | | | | | | |
| Female | 70 | (50) | 58 | (52) | 12 | (41) |
| Male | 70 | (50) | 53 | (48) | 17 | (59) |

The dependent variable was enrollment in the subsequent developmental math course after passing the first course within one year (enrolled in second class = 1, did not enroll in second class = 0). The independent variables used were age (traditional = 1, non-traditional = 0), sex (female = 1, male = 0), race (White = 1, non-White = 0), and sequence length (post-reform 2-course = 1, pre-reform 4-course = 0). The analysis resulted in a statistically significant model, $\chi^2(4, N = 700) = 56.95$, $p < .01$. The Cox and Snell pseudo $R^2$ was .078 and the Nagelkerke pseudo $R^2$ was .107, indicating that the model did not account for a large portion of the variance. The model showed an overall correct prediction rate of 62.6%. The first part of Table 10 shows the regression coefficients, standard errors, Wald test, and odds ratios with 95% confidence intervals.

The Wald test indicated that sequence length was the only statistically significant predictor variable ($p < .01$). Students who were in the pre-reform 4-course sequence had 3.98 times the odds of enrolling in a second course within one year, $OR = 3.98$, 95% CI [2.66, 5.95], with the confidence interval indicating that it was between 2.66 and 5.95 times the odds of enrolling in the subsequence course within one year when controlling for age, sex, and race.

Another binary logistic regression was analyzed for the students with an unidentified ethnicity using age, sex, and sequence length to predict enrollment in the subsequent course within one year. The sample for this question included all students with an unidentified ethnicity who passed their first course ($N = 140$) and is described in the second part of Table 9. The analysis resulted in a statistically significant model, $\chi^2(3, N = 140) = 12.36$, $p < .01$. The Cox and Snell pseudo $R^2$ was .085 and the Nagelkerke pseudo $R^2$ was .116, indicating that the model did not account for a large portion of the variance. The model showed an overall correct prediction rate of 65.0%. The second part of Table 10 shows the regression coefficients, standard errors, Wald test, and odds ratios with 95% confidence intervals.

The Wald test indicated that sequence length was the only statistically significant predictor of enrolling in the subsequent course within one year ($p < .01$). Students in the pre-reform 4-course sequence whose ethnicity was unidentified had 6.33 times the odds of enrolling in their second course within one year when controlling for age and sex, *OR*

= 6.33, 95% CI [1.79, 22.22]. However, the confidence interval for this odds ratio was quite broad, indicating it could be between 1.79 and 22.22 times the odds and therefore, fairly imprecise.

**Table 10**

*Regression Coefficients of Lowest-Level Mathematics Student Characteristics and Sequence Length on Enrollment in Second Course within One Year*

| Variable | *B* | *SE* | *OR* | 95% CI | Wald Statistic | *p* |
|---|---|---|---|---|---|---|
| | | | Identified Ethnicity ($N$ = 700) | | | |
| Age[a] | –0.04 | 0.19 | 0.97 | [0.66, 1.41] | 0.03 | .86 |
| Sex[b] | 0.02 | 0.16 | 1.02 | [0.74, 1.41] | 0.16 | .91 |
| Race[c] | –0.28 | 0.17 | 0.76 | [0.54, 1.07] | 2.54 | .11 |
| Sequence Length[d] | –1.38 | 0.20 | 0.25** | [0.17, 0.38] | 44.90 | < .01 |
| | | | Unidentified Ethnicity ($N$ = 140) | | | |
| Age[a] | 0.39 | 0.42 | 1.48 | [0.65, 3.36] | 0.89 | .35 |
| Sex[b] | 0.12 | 0.37 | 1.12 | [0.54, 2.32] | 0.10 | .76 |
| Sequence Length[d] | –1.84 | 0.64 | 0.16** | [0.05, 0.56] | 8.21 | <.01 |

*Note.* CI = confidence interval for odds ratio (*OR*).

[a] 0 = non-traditional age and 1 = traditional age. [b] 0 = male and 1 = female. [c] 0 = non-White and 1 = White. [d] 0 = 4-course sequence and 1 = 2-course sequence.

*$p < .05$. **$p < .01$.

***Re-Enrollment Within Two Years***

A binary logistic regression was used to address the extent to which age, sex, and race predicted whether a student with the lowest-level placement score and who passed their first course would enroll in their second course within two years. The sample for this question included all students who earned a passing grade in their first course and for whom two years of data were available (*N* = 566) and is described in the first part of Table 11.

**Table 11**

*Descriptive Statistics of Students by Pre- and Post-Reform for all Students for Whom Two Years of Data were Available*

| Characteristic | Total | | Pre-Reform | | Post-Reform | |
|---|---|---|---|---|---|---|
| | *N* (%) | | *n* (%) | | *n* (%) | |
| Identified Ethnicity (*N* = 566) | | | | | | |
| Age | | | | | | |
| Traditional | 436 | (77) | 380 | (78) | 56 | (71) |
| Non-Traditional | 130 | (23) | 107 | (22) | 23 | (29) |
| Sex | | | | | | |
| Female | 301 | (53) | 254 | (52) | 47 | (60) |
| Male | 265 | (47) | 233 | (48) | 32 | (40) |
| Race | | | | | | |
| White | 374 | (66) | 323 | (66) | 51 | (65) |
| Non-White | 192 | (34) | 164 | (34) | 28 | (35) |
| Unidentified Ethnicity (*N* = 121) | | | | | | |
| Age | | | | | | |
| Traditional | 85 | (70) | 76 | (70) | 9 | (75) |
| Non-Traditional | 36 | (30) | 33 | (30) | 3 | (25) |
| Sex | | | | | | |
| Female | 61 | (50) | 57 | (52) | 4 | (33) |
| Male | 60 | (50) | 52 | (48) | 8 | (67) |

The dependent variable was enrollment in the subsequent developmental math course after passing the first course within two years (enrolled in second class = 1, did not enroll in second class = 0). The independent variables used were age (traditional = 1, non-traditional = 0), sex (female = 1, male = 0), race (White = 1, non-White = 0), and sequence length (post-reform 2-course = 1, pre-reform 4-course =0). The analysis resulted in a statistically significant model, $\chi^2(4, N = 566) = 13.60$, $p < .01$. The Cox and Snell pseudo $R^2$ was .024 and the Nagelkerke pseudo $R^2$ was .032, indicating that the model did not account for a large portion of the variance. The model showed an overall correct prediction rate of 55.1%. The first part of Table 12 shows the regression coefficients, standard errors, Wald test, and odds ratios with 95% confidence intervals.

The Wald test indicated that sequence length was the only statistically significant predictor variable ($p < .01$). Students who were in the pre-reform 4-course sequence had 2.48 times the odds of enrolling in a second course within two years than students in the post-reform 2-course sequence, *OR* = 2.48, 95% CI [1.46, 4.18]. However, once again, the broad confidence interval indicated an imprecise odds ratio. Furthermore, the overall correct prediction rate of 55.1% of the model may not be reliable.

Another binary logistic regression was analyzed for students with an unidentified ethnicity using age, sex, and sequence length to predict enrollment in the subsequent course within two years. The sample for this question included all students with an unidentified ethnicity who passed their first course ($N = 121$) The analysis resulted in a statistically significant model, $\chi^2(3, N = 121) = 8.03$, $p < .05$. The Cox and Snell pseudo $R^2$ was .064 and the Nagelkerke pseudo $R^2$ was .086, indicating that the model did not account for a large portion of the variance. The model showed an overall correct prediction rate of 58.7%. The second part of Table 12 shows the regression coefficients, standard errors, Wald test, and odds ratios with 95% confidence intervals. The Wald test indicated that sequence length was the only statistically significant predictor of enrolling in the subsequent course the within two years ($p < .01$). Students in the pre-reform 4-course sequence whose ethnicity was unidentified, had 8.70 times the odds of enrolling in a second course within two years of passing their first course, than students in the post-reform 2-course sequence when adjusting for age and sex *OR* = 8.70, 95% CI [1.07, 71.43]. But with a very broad confidence interval with the lower limit close to 1, it may not be a strong predictor.

However, it is worth noting that of all students with an unidentified ethnicity with the lowest-level placement exam scores who passed their first developmental mathematics course, 10% enrolled in the subsequent course and none passed their second course. Finally, although students are probably more likely to not enroll in the subsequent course after passing their first course in the pre-reform 4-course sequence than in the post-reform 2-course sequence, it is still possible that higher percentages of students are completing their entire sequence in the post-reform program as there are fewer opportunities for them to not re-enroll. Data from longer time periods should be studied to examine this issue.

**Table 12**

*Regression Coefficients of Lowest-Level Mathematics Student Characteristics and Sequence Length on Enrollment in Second Course within Two Years*

| Variable | *B* | *SE* | *OR* | 95% CI | Wald Statistic | *p* |
|---|---|---|---|---|---|---|
| | | | Identified Ethnicity (*N* = 566) | | | |
| Age[a] | –0.01 | 0.20 | 0.99 | [0.67, 1.48] | <0.01 | .96 |
| Sex[b] | –0.08 | 0.17 | 0.93 | [0,66, 1.30] | 0.20 | .65 |
| Race[c] | –0.16 | 0.18 | 0.86 | [0.60, 1.22] | 0.73 | .40 |
| Sequence Length[d] | –0.91 | 0.27 | 0.40** | [0.24, 0.68] | 11.45 | <.01 |
| | | | Unidentified Ethnicity (*N* = 121) | | | |
| Age[a] | 0.20 | 0.42 | 1.22 | [0.538, 2.76] | 0.22 | .64 |
| Sex[b] | 0.30 | 0.38 | 1.35 | [0.640, 2.85] | 0.38 | .43 |
| Sequence Length[d] | –2.16 | 1.07 | 0.12** | [0.014, 0.93] | 1.07 | <.01 |

(continued)

*Note.* CI = confidence interval for odds ratio (*OR*).

[a] 0 = non-traditional age and 1 = traditional age. [b] 0 = male and 1 = female. [c] 0 = non-White and 1 = White. [d] 0 = 4-course sequence and 1 = 2-course sequence.

*$p < .05$. **$p < .01$.

***Pre- and Post-Reform Students***

For this study, students were categorized as part of the pre-reform group or post-reform group. However, there were students ($N = 107$) who enrolled in the lowest-level course of the pre-reform 4-course sequence and then, whether they passed or failed the first course, enrolled in the lowest level of the post-reform 2-course sequence. Of these students, 86% passed their first course. Of those who passed their first course, 68.6% passed their second course. Of those who did not pass their first course, 21.4% passed the second course. Further study of this group of students should be done to examine their progression, or lack of, throughout the developmental mathematics sequence.

**Summary**

The sample size for this study, by nature of the chronological order of research questions, decreased with each analysis. Additionally, the analyses examined whether students who passed their first developmental mathematics course enrolled into the subsequent course included differences in sample size of the pre-reform and post-reform groups. Enrollment in the department had decreased overall as some freshmen requirements, such as mandatory placement and mandatory enrollment into English and mathematics courses were either removed or not enforced. Future studies should examine the outcomes of students who delay placement and enrollment into any developmental mathematics courses as they begin their college career, particularly first-generation students who may be less aware of the consequences of such a delay.

The original design for this study included using a regression to examine the extent to which age, sex, race, and sequence length predicted GPA in the first and second developmental mathematics courses for students with the lowest placement exam scores. However, due to lack of normality in the GPA scores for these courses, the analysis was changed to chi-squared tests of association to examine the relationship of these variables. Binary logistic regression was used for all dichotomous outcome variables, including completion of courses and enrollment of subsequent developmental mathematics courses after passing the first course.

The analyses conducted in this study resulted in varying levels of significance for statistical findings for each variable. Traditional-aged students showed a statistically significant relationship with failing their first course, however the effect size was small ($\phi = -.13$). Sex, male or female, did not result in statistical significance in any of the models created in this study. Students who attempted their second course in their assigned sequence for the first time showed more than twice the odds of completing that course, however the confidence interval for this finding was broad and indicated that the effect may not actually be as strong as suggested by the odds ratio. There was also a relationship between students who were in their first attempt of their second course in the sequence and receiving a passing grade, but the effect size was fairly small ($\phi = .21$).

Race, White or non-White, also was statistically significant in some models of this study. White students were found to have a statistically significant relationship with passing their first course, but the effect size was very small ($\phi = .09$). Additionally, White students had a reduction in odds of completing their second course in their assigned sequence compared to non-White students.

Sequence length showed a strong relationship or was a statistically significant predictor of several of the student success outcomes studied. For students with an unidentified ethnicity, the shorter sequence length of the post-reform program reduced the odds of completing their second course. There was also a relationship between the shorter sequence length of the post-reform program and students receiving a failing grade in their second course for both identified and unidentified ethnicity, with moderately strong effect sizes ($\phi = -.344$, $\phi = -.2$, respectively). Finally, among students with the lowest levels of placement exam scores who passed their first developmental mathematics course, post-reform students were less likely to enroll in the subsequent course within one year and within two years for both identified and unidentified ethnicities. Although, enrolling within two years for students with an unidentified ethnicity had a much broader confidence interval which could indicate that the change in likelihood may not be as meaningful.

In the future, further studies should be done with additional predictor variables, such as Pell Grant eligibility and first-generation status to increase model significance of the logistic regressions. Additionally, future studies should include larger sample sizes, particularly of post-reform students to increase the predictability of the models and effect sizes. Other future analyses should focus on students with the lowest placement exam scores who do not enroll in the subsequent developmental mathematics course after passing the first course. Other studies could follow students and their progression further along in their college career to determine if they completed their entire developmental mathematics sequence, enrolled in, completed, and passed a college-level mathematics course, and graduated. Finally, although the results of this study show that students in the post-reform 2-course sequence were less likely to enroll in the second developmental mathematics course after passing the first course, it is possible that the 2-course sequence results in higher rates of sequence completion among students with the lowest-level placement exam scores. Further analyses should be conducted to using a longer time frame to determine the extent to which sequence length predicts completion of the entire sequence within two and three years.

# CHAPTER V

## Discussion

Developmental mathematics education programs are continually changing as programs and administrators implement new course structures in hopes of improving student outcomes. Students who enter these programs with the lowest levels of placement exam scores must be considered and their outcomes examined to determine the best approach for them. This study began with an explanation of the problem of poor performance outcomes by students whose placement exam scores were at the lowest levels and an exploration of the various types of program changes and redesigns that institutions of higher education have implemented. The literature available in the field of developmental mathematics and the success outcomes of its students in higher education were explored and found to be lacking in focus on students with the lowest levels of placement exam scores. Many structural changes to developmental mathematics programs have been implemented, but their effect on these students in particular must be inspected closely to ensure that developmental education programs are reaching students at the highest levels of risk for low success. The purpose of this study was to examine the extent to which the number of courses required in a developmental mathematics sequence effected student success outcomes for students with the lowest levels of standardized placement exam scores.

The student success outcomes assessed in this study were originally planned to be whether a student completed their first and second course in the developmental mathematics sequence and their GPA in these same courses. However, as the available data did not meet the assumption of normality, the researcher chose instead to assess the extent to which sequence length was related to whether a student completed their first and second course in the developmental mathematics sequence and whether they received a passing or failing grade in these same courses while controlling for age, sex, race, and number of attempts. Additionally, students with identified and unidentified ethnicities were separated and each analysis was completed for both groups. It was found that, for students with an identified ethnicity, Whites experienced an increase in likelihood of passing their first course, but, interestingly, experienced a decrease in likelihood of completing their second course. Furthermore, students attempting a course for the first time were also more likely to complete and pass their second course. Among students who did not identify their ethnicity, students attempting a course for the first time were once again more likely to pass their second class and traditional-aged students were less likely to pass their first course. Finally, among students with an unidentified ethnicity, students in the pre-reform 4-course sequence were more likely to complete and pass their second course.

The researcher, motivated by observations of the number of students with low-level placement exam scores who passed their first course, but then did not re-enroll in the subsequent course, added additional analyses to this study. It was found that students in the pre-reform 4-course sequence who passed their first course in the developmental mathematics sequence were more likely to re-enroll in the subsequent course in the sequence within both one and two years when controlling for age, sex, and ethnicity. However, broad confidence intervals among all of these findings require further dialogue and examination and will be discussed in this chapter.

## Interpretation of Findings

The findings of this study could be consequential, although more data from a longer period would likely increase the implications for practice. However, these findings are still meaningful as they point to what could be happening with the lowest-level developmental mathematics students and their academic outcomes. These results also help to uncover issues that need to be addressed within developmental mathematics to ensure all students have the opportunity at a successful college career.

### *Completion*

Enrollment in the first developmental mathematics course for the students with the lowest levels of placement exam scores is only the first step. Continuing throughout the course without withdrawing is an issue for many students that needs to be addressed (Bailey et al., 2010; Engstrom & Tinto, 2008). This study examined student completion of their first and second developmental mathematics courses, defined as receiving a final letter grade in the course rather than a final mark of Withdraw (W) or Unofficial Withdraw (UW). Utah Valley University sets the deadlines for when a student may receive a W or UW in the course and there are students who do not qualify for a W or UW despite lack of participation in the course for the majority of the semester. However, a student who withdraws all effort and participation in a course within approximately the first half of the semester and a student who withdraws within approximately the second half of the semester may have different circumstances and needs that can be addressed at the instructor level or the advisor or administration level. Therefore, completion of the course and whether a student earned a passing grade in a course were examined separately in this study.

A binary logistic regression was performed to examine the extent to which sequence length affected completion of the first and second developmental mathematics course for students with the lowest-level placement scores, controlling for age, sex, race, and attempt number among students who identified their ethnicity. Although there was no statistically significant finding for completion of the first course, there were statistically significant findings for the effect on completion of the second course. Interestingly, non-Whites had almost three times the odds of completing their second course compared to Whites. This finding differs from the results of multiple studies which show that ethnicity either did not affect student retention (Fike & Fike, 2008) or that minority students had lower rates of progression through their coursework (Bahr, 2010b; Fong et al., 2015; Hoyt, 1999; Wolfle & Williams, 2014).

However, this finding may not be surprising given that the almost 20% of the students included in this study did not identify their ethnicity. Minority students regularly underreport their ethnicity when self-reported due to a perceived lack of social support (Rochon et al., 2004; Wallace & Bachman, 1993) and it is very possible that a high proportion of the students in this sample without an identified ethnicity are minority students who chose not to disclose. Furthermore, students who did disclose a minority ethnicity may have had more positive non-cognitive factors affecting their outcomes, such as family support, motivation, and self-efficacy. Finally, as with many of the findings of this study, the confidence interval was broad and indicated that non-Whites had could have only 1.34 times the odds of completion of their second course compared to non-Whites, or as much as 5.56 times the odds of completion.

Students with an unidentified ethnicity were analyzed separately to determine the extent to which sequence length affected completion of their second course while controlling for age, sex, and attempt number. Sequence length was the only statistically significant variable in this model ($p < .05$) and indicated that the pre-reform 4-course sequence increased the odds of completing the second course over five times that of students in the post-reform 2-course sequence. Other studies have found that students in shorter sequences were either just as likely as students in longer sequences to complete their developmental mathematics sequence (Lucas & McCormick, 2007), or more likely to complete their developmental mathematics sequence and more likely to complete a college-level mathematics course (Bailey et al., 2010; Martinez, 2018; Schudde & Keisler, 2019). However, none of these studies examined whether students who enrolled in the lowest-level mathematics course withdrew from the course during the semester, but instead seem to combine these students with those who received a failing grade.

Similar to students who pass a developmental mathematics course, but then do not enroll in the subsequent course (Bailey et al., 2010; Edgecombe, 2011; Scott-Clayton & Rodriguez, 2012), students who withdraw from or stop participation in a course could have very different factors that led to the lack of a successful outcome than students who persist throughout the semester, but were unable to achieve a passing grade. In this sample of students with an unidentified ethnicity and who enrolled in a second developmental mathematics sequence, almost 13% received a final grade of W or UW. Nevertheless, the unique finding of this study must be balanced with the lack of a variable controlling for race and the accompanying broad confidence interval. The effects of race on the success of a student who chose not to disclose their ethnicity to the university is unknown and, with such a high portion of students from the sample in this category, could change the overall results. Even more important than race itself could be the underlying reasons a student had for not identifying their race and the extent to which those reasons affect student success. The broad confidence interval indicated that students in the pre-reform 4-course sequence could be as little as 1.41 times as likely to complete their second course, or the notable possibility of as much as 21.74 times as likely to complete their second course. Although the new 2-course sequence may have led to similar probabilities of completing the developmental mathematics course, it is also possible that it had exceedingly detrimental effects on students with an unknown ethnicity, but the broad confidence interval strongly suggests that no reliable conclusions can be made.

Among students who identified their ethnicity, number of attempts was the only other statistically significant predictor variable. Students for whom enrollment in their second course was their first attempt at that course had approximately 2 times the odds of completing that course than students who had previously failed that course. Despite a broad confidence interval, this finding is consistent with other researchers who caution that students who fail a developmental mathematics course in their first year do not benefit from advantages of academic momentum and are at much higher risk of a continued lack of success going forward (Bettinger & Long, 2005b; Fike & Fike, 2008; Goldrick-Rab, 2007). A student with the lowest levels of placement exam scores who is enrolled in a developmental mathematics course which they had previously failed requires considerable efforts and interventions on the part of instructors and advisors to ensure continued opportunities for success.

***Pass/Fail***

Students at UVU who complete a given course are given a letter grade along the traditional 4-point scale, although UVU uses E's instead of F's to indicate a GPA of 1.0. A passing grade in a developmental mathematics course was generally a C-, or 1.7 GPA, except for the course immediately preceding a college-level mathematics course, which requires a C, or 2.0 GPA to be considered passing. Students who receive a letter grade have participated in the course until at least the approximate half-way point of the semester, although some will have not continued their efforts throughout the entirety of the course. A passing grade is what will permit them to enroll in the subsequent mathematics course. In the pre-reform 4-course sequence, the first developmental mathematics course for students with the lowest-level placement exam scores was Fundamentals of Mathematics and the subsequent course was Foundations for Algebra, both of which required a C- to be considered passing. In the post-reform 2-course sequence, the first developmental mathematics course for students with the lowest-level placement exam scores was called Foundations for Algebra and the subsequent course was Integrated Beginning and Intermediate Algebra. The new Foundations for Algebra course still required a grade of C- to pass the course, but the second, and last, course in the new developmental mathematics sequence required a grade of C to pass the course. Whether a student passed, or failed a given course was determined by and coded according to which course they took.

A chi-squared test of association was conducted to determine the extent to which there was a relationship between age, sex, ethnicity, attempt number, and sequence length with whether or not a student with the lowest placement exam scores passed their first or second course in the developmental mathematics sequence. Once again, race was a statistically significant variable, but in this instance, Whites had a positive relationship with passing their first class , although a small effect size. This finding is more in line with the results of other studies (Bahr, 2010b; Fong et al., 2015; Hoyt, 1999; Wolfle & Williams, 2014), but seems to contradict the earlier finding of this study that non-Whites were more likely to complete their second course. However, the combination of a large sample size and low effect size could have led to statistically significant results that may not be meaningful. The issue of a large portion of students in this sample not identifying their ethnicity could, once more, play a role in this outcome. Nevertheless, the findings of many researchers who have found that minorities are at a systemic disadvantage (Attewell et al., 2006; Chen, 2016; Feldman, 1993), particularly in developmental education (Bahr, 2010b), should not be overlooked. The effects that ethnicity on student success outcomes must be continually studied and, as is the case at UVU, the reasons a student may not want their ethnicity on record should be addressed.

Also, among students who identified their ethnicity, the first attempt in a course was found to have a statistically significant relationship with passing the second course taken by these students. This relationship was strong and indicated that students in their first attempt at a course experience much higher passing rates than students who are repeating a course. There were multiple factors that likely contributed to this, such as academic momentum, motivation, and an increase in self-efficacy due to previous success. The consequences of this finding should be increased student support structures at the institution and encouragement from instructors and advisors for students to pass their developmental mathematics courses on their first attempt alongside additional supports for students who have previously failed a developmental mathematics course.

For students with an unidentified ethnicity, another chi-squared test of association was conducted to evaluate the relationship between age, sex, attempt, and sequence length with whether a student with the lowest-level placement exam scores passed their first and second developmental mathematics course. Among these students, age had a statistically significant relationship with passing the first class and sequence length had a statistically significant relationship with passing the second class. Similar to Feldman's (1993) study of first-year retention of community college students which found that non-traditional-aged students were least likely to drop out, this study's finding suggests that maturity level could affect motivation to succeed for students taking their first developmental mathematics course. Although a somewhat small effect size, this finding is also similar to a study by Calcagno et al. (2007), who found that students over the age of 25 are more likely to complete a degree when controlling for mathematical ability. The results of this study imply that even among students with the lowest-level placement exam scores, older students are more likely to succeed and that traditional-aged students may need more support in the transition to college coursework.

Also, among students with an unidentified ethnicity, a shorter sequence length was found to have a negative relationship with students passing their second course. Combined with the finding earlier in this study, students in the pre-reform 4-course sequence had increased completion rates and increased passing rates in their second course. The moderately strong effect size of this finding indicated that students with an unidentified ethnicity may be more likely to succeed in their second course if it is part of a more spread out sequence compared to a compressed sequence where the second course is the immediate predecessor of a college-level mathematics course. However, as a result of the limited time frame of this study, it is unclear if the increased passing rates in the second course of the pre-reform 4-course sequence leads to increased completion rates of the developmental mathematics sequence. Despite greater success at an earlier course, students who pass their second of four courses still have two more classes to pass prior to completing their entire sequence. Developmental mathematics program administrators and instructors must carefully weigh the possibility of higher numbers of students eventually moving on to a college-level course with the possibility of higher numbers of students failing out in their first year of college.

***Re-Enrollment***

Open enrollment institutions of higher education, such as UVU, are bound to have elevated rates of student attrition. Many of the reforms to developmental mathematics programs were implemented in efforts to slow down the rates at which students who, even when passing a course, fail to enroll in another developmental mathematics course as part of their progress toward a degree (Bailey et al., 2010; Edgecombe, 2011; Goldrick-Rab, 2010; Kosiewicz et al., 2016; Lucas & McCormick, 2007; Pain, 2016; Schudde & Keisler, 2019). The developmental mathematics program at UVU made reforms to its sequence by compressing the mathematical concepts of a 4-course sequence into an accelerated 2-course sequence, but students are able to delay enrollment into developmental mathematics coursework, whether their first or second course, and pursue their major in courses without a mathematics prerequisite. The effect that this change had on student success outcomes was the focus of this study and, in addition to the original research questions foundational to this study, the data revealed the need for further examination of these effects.

Based on literature, it was expected that many students would use exit-points in the sequence to drop out, but students' progression through their assigned developmental mathematics sequence showed drastic declines between students who passed their first course and students who then enrolled in the subsequent course. Thus, additional binary logistic regression analyses were performed to determine the extent to which sequence length predicted whether a student with the lowest-level placement score and who passed their first course in the developmental mathematics sequence would enroll in their second course within one year and two years, while controlling for age, sex, and ethnicity. Once again, analyses were conducted separately for both students who identified their ethnicity and students who did not.

For both students with identified and unidentified ethnicities, the only statistically significant predictor variable for enrolling in a subsequent developmental mathematics course after passing the first course was sequence length for both enrolling within one year and within two years. Students with an identified ethnicity and the lowest-level placement scores in the pre-reform 4-course sequence had almost four times the odds of enrolling in the subsequent course within one year, and more than twice the odds of re-enrolling within two years, of passing their first course than those in the post-reform 2-course sequence. For students with an unidentified ethnicity and the lowest-level placement scores in the pre-reform 4-course sequence had over six times the odds of enrolling in the subsequent course within one year, and almost nine times the odds of re-enrolling within two years of passing their first course than those in the post-reform 2-course sequence.

The 95% confidence intervals for these analyses are quite broad, particularly for students with an unidentified ethnicity and suggest that the odds of enrollment in the second developmental mathematics course may not be greater for students in the 4-course sequence than the 2-course sequence, if at all. However, despite the inability to conclude that the pre-reform 4-course sequence was better for students, it is quite likely that the post-reform 2-course sequence is not an improved program for students and might be inferior in addressing the issue of student attrition between semesters.

Many researchers have concluded that developmental mathematics programs in their entirety have no effect (Boatman & Long, 2018) or a negative effect on student success outcomes Brower et al., 2017; Martinez, 2018; Melguizo et al., 2016; Xu & Dadgar, 2018). Additionally, claims that the length of the developmental mathematics sequence has a direct negative relationship on these student outcomes by allowing for more attrition are found in many studies (Bailey et al., 2010; Edgecombe, 2011; Melguizo et al., 2016; Scott-Clayton & Rodriguez, 2012). Furthermore, although incoming mathematical ability is one of the most consequential factors related to persistence in college (Bahr, 2008, 2009, 2010a; Bremer et al., 2013; Burns, 2010; Conley, 2007; Hawley & Harris, 2005; Hoyt, 1999; Li et al., 2013; Perin & Charron, 2019), the relationship between sequence length and re-enrollment in subsequent developmental mathematics courses after passing a course has not been clearly examined for students with the lowest-level placement exam scores. A compressed, shorter developmental mathematics sequence did not resolve or even address the issue of exit-points at UVU.

Although there are reports of compressed courses that increased continued enrollment in their sequence (Bragg et al., 2010; Edgecombe, Jaggars, et al., 2013; Jaggars et al., 2015), the students in this sample may not have had similar characteristics. Students who delayed enrollment into a second semester of developmental mathematics coursework may have been influenced by a multitude of factors. Like all higher education institutions, but particularly as one fulfilling both the roles of community college and university to the surrounding community, UVU has a unique student population with varying academic needs and personal obstacles. Additionally, the lack of mandatory placement or enrollment policies allow students to delay their enrollment in any developmental mathematics, even while pursuing coursework in their major that do not have mathematics prerequisites, some even waiting until their final year to fulfill their mathematics requirements. It may be that students chose to delay their mathematics courses with the assumption that they would enroll in a future semester, but the time away from the subject may have discouraged them from following through. Furthermore, without the addition of more advisors for developmental mathematics students, they may not have been advised on the pacing of an accelerated program and the continual commitment required to succeed. Finally, overlapping mathematical concepts were removed from coursework to shorten the sequence. Students with the lowest placement exam scores may need more review time at the beginning of subsequent courses to maintain confidence and combat mathematics anxiety.

Student outcomes at UVU need to be studied further as the reformed program becomes more established and a longer time period can be examined, but issues surrounding retention and attrition of developmental mathematics students cannot be solved by compressing a sequence alone. Persistence in the first year of college for developmental students is greatly influenced by the developmental education programs in which they participate (Engstrom & Tinto, 2008). Students with the lowest levels of mathematical ability require more than just changing a 4-course sequence into a 2-course sequence to improve success outcomes. Rather, the most vulnerable of students require placement practices which include non-cognitive factors, intensive advising, and institutional holistic support structures in their first year and throughout their college career.

**Implications for Theory**

The role of developmental education is to meet the needs of high-risk students. It is an adjustment of education for students who require assistance to reach the level of college readiness required for success and, therefore, must be tailored to the students it serves. The conceptual framework for this study was focused on adaptive teaching and its elements as put forth by Kulik and Kulik (1991) in their discussion of developmental instruction and the theoretical foundations of developmental education. Holistic developmental education programs include more than just remediation. Rather, they provide coursework, advising, counseling, tutoring, and support services. Effective programs will consider both cognitive and non-cognitive facets of student learning to combat common issues of developmental students (Rutschow, 2019b; Scrivener et al., 2015; Sommo & Ratledge, 2016).

An adaptive teaching method is an approach to education that requires institutions, programs, and instructors to identify beneficial methods of instruction and to match the needs of their students. The individual characteristics of students that must be considered include the ideal rate of learning for each student, whether a traditional, longer course sequence or an accelerated shorter sequence. Adaptive teaching is flexible and those who practice it recognize students as unique individuals who require adaptable approaches to learning and instruction. Many of the shortened, accelerated developmental mathematics program course sequences are designed with hopes that the ideal learning rate for their students is much quicker than is traditionally believed and that student success outcomes will improve among their developmental students as a result (Bailey et al., 2010; Edgecombe, 2011; Martinez, 2018; Schudde & Keisler, 2019; Scott-Clayton & Rodriguez, 2012). This study used this conceptual framework to examine the effects that a shortened sequence had on those students at the lowest levels of incoming mathematical ability. As suggested by this framework, if acceleration or compression of developmental mathematics courses meets the varied needs of developmental mathematics students at a particular institution more effectively than a traditional longer sequence, improvements should be seen among various student success outcome measures.

In this study, binary logistic regression models were created to determine the extent to which sequence length predicts completion of developmental mathematics courses and whether a student enrolls in the subsequent course in the developmental mathematics sequence after passing their first course for students with the lowest-level placement exam scores. Controlling for various combinations of variables such as age, sex, race, and attempt, these models were built to uncover the portion of variance in outcomes that can be contributed to sequence length. However, goodness of fit measures consistently showed that these models were not highly predictive.

The model to predict completion of the first class for the lowest-level placed students with an identified ethnicity was not statistically significant and the model to predict completion of the second class, though statistically significant, had a Nagelkerke pseudo $R^2$ of .102, indicating that this model was not a good fit. Additionally, the models to predict enrollment in the subsequent course in the developmental mathematics sequence for students with an identified ethnicity within one year and within two years of passing the first course Nagelkerke pseudo $R^2$ values of .107 and .032, respectively. For students with an unidentified ethnicity, the models to predict enrollment in the subsequent course in the developmental mathematics sequence within one year and within two years of passing the first course had Nagelkerke pseudo $R^2$ values of .116 and .086, respectively. Furthermore, the models predicting re-enrollment in subsequent courses within one year for students with both identified and unidentified ethnicities had correct prediction rates of just over 60% and just over 55% correct prediction rates for the models predicting re-enrollment within two years: not much better than flipping a coin. The goodness of fit measures clearly show that these models do not include the factors and student characteristics that have a meaningful effect on student success outcomes.

Variables such age, sex, race, and number of attempts only accounted for very small portions of variance in student success, suggesting that these demographic variables have less impact than other cognitive and non-cognitive factors. Sequence length as a predictor variable also did not result in highly predictive models for students with the lowest-level placement exam scores. These results indicated that sequence length alone does not have a profound effect on student outcomes and, therefore, does not meet the conditions of adaptive teaching. Adaptive teaching is the antithesis of a "one size fits all" approach to education and acknowledges that a single method of instruction or assessment does not result in the same outcomes for all students (Kulik & Kulik, 1991). A shorter timeline to complete a developmental mathematics sequence has been part of successful reforms when targeted at students who were able keep up with the pace (Bragg et al., 2010; Edgecombe, Jaggars, et al., 2013; Jaggars et al., 2015). Developmental programs that utilize adaptive teaching methods should provide approaches and paths to learning that meet the various needs of the particular students in that program, including the ideal rate of learning for each student. This could include an accelerated sequence model in a developmental mathematics program that requires less calendar time than is traditionally provided but should not require that all students move through programs at that accelerated rate. Acceleration as part of holistic program based on sound learning and instructional theory, as suggested by Kulik and Kulik (1991) has a much greater potential to improve student success for underprepared college students. Such a program would allow for multiple student learning rates alongside increased student support services, instruction on learning strategies, and accommodations for a diverse population of incoming students, particularly those at the lowest levels of mathematical ability.

**Implications for Practice**

This study examined the practice of reducing the number of courses in a developmental mathematics sequence to determine the effects of these compressed sequences on students with the lowest-level placement exam scores. Although odds ratios and chi-squared tests of association suggested that the post-reform 2-course sequence reduced the likelihood of completion, passing, and re-enrollment in developmental mathematics courses, the accompanying broad confidence intervals do not allow it to be determinately said that a shorter sequence is worse for students at the lowest levels of mathematical ability than a longer sequence. However, it is likely that a shorter sequence is not better for these same students, especially without other, more holistic, programmatic changes.

Proponents of accelerated programs in developmental education have argued that traditional 3- and 4-course developmental mathematics sequences are not meeting the needs of underprepared college students (Bailey et al., 2010; Edgecombe, Cormier, et al., 2013; Scott-Clayton & Rodriguez, 2012), which this study does not disprove. However, isolated changes to the structure of these sequences or programs also do not meet the needs of underprepared college students. Kulik and Kulik (1991) state that “traditional educational approaches are too rigid and inflexible because they prescribe the same instructional conditions for all learners, no matter what their initial aptitude and no matter what their responses to instruction” (p. 11). If 3- and 4-course sequences where all students are put on the same pathway are not meeting the needs of underprepared students because they are inflexible, then a shortened sequence, or no developmental education at all, where once again students are all put on the same pathway, faces the same problem.

This study suggests that acceleration alone does not have a large impact on overall success of students with the lowest levels of placement exam scores, although it can, and perhaps should play a part in efforts to improve student success (Boylan, 2004). Developmental mathematics instructors, program directors, and administrators at UVU should consider holistic programmatic changes other than just sequence structure to help all students. Effective changes to the developmental mathematics program should include all-inclusive, high-touch advising (Bragg et al., 2010; Edgecombe, Jaggars, et al., 2013; Scrivener et al., 2015; Sommo & Ratledge, 2016); multi-factor placement policies (Saxon & Morante, 2015; Scott-Clayton, 2012); support for cognitive and non-cognitive factors, such as family support, motivation, and self-efficacy (Rutschow, 2019b; Scrivener et al., 2015; Sommo & Ratledge, 2016); and a focus on the first year experience (Engstrom & Tinto, 2008; Fike & Fike, 2008; Hawley & Harris, 2005; Jenkins & Bailey, 2017).

This study found other specific factors that affect student success at UVU that should also be addressed as part of the developmental mathematics program. Too many students at the lowest-level mathematical ability in both the pre-redesign 4-course sequence and the post-redesign 2-course sequence who pass their first developmental mathematics course do not enroll in the subsequent course in their sequence. Interventions for these students can include advisors following up with students after they have passed their first class to promote continued enrollment the following semester. Additionally, instructors teaching the lowest-level course in the developmental mathematics sequence should encourage students by helping them recognize the progress made by passing their first class and expressing the importance of continuing with that momentum. Furthermore, administrators could allow students to register for developmental mathematics courses for two semesters at the start of their first year which would move the burden of re-enrollment away from students who want to continue to the next class. Finally, orientation to developmental education and what it means for students placed into developmental mathematics should be integrated into any potential first-year experience initiatives for at UVU.

Open enrollment institutions of higher education have the added responsibility of educating students of all ability levels. It is at these institutions that some adults can find their only chance at pursuing knowledge and reaching their educational potential. Students who enter UVU at the lowest levels of mathematical ability and who are placed into the lowest-level course of developmental mathematics are at high risk of attrition and failure. It is these very students that UVU and other schools like it must provide not just access to higher education, but support for success (Engstrom & Tinto, 2008). The students, UVU, and the surrounding community will all benefit from a developmental mathematics program that allows students with the greatest needs to benefit from transformational potential of a college education.

**Limitations and Recommendations for Future Research**

This study, as all similar studies, had limitations in its ability to examine the effects of a change in sequence length on students with the lowest levels of mathematical ability. Issues such as smaller sample sizes and limited time frames were present but should be addressed in future research. Future studies and researchers have the opportunity to further explore acceleration in developmental mathematics along with other factors which may have an impact on student success. Additional research will build on this study to provide more clarity on what members of developmental mathematics programs can do to enact meaningful change.

***Limitations and Validity***

All research has limitations and there were several in this study. First, students were placed into developmental mathematics courses based solely on a placement exam score instead of a multi-factor approach which would increase accuracy. Additionally, scores of several different placement exams were accepted (ACT, ACCUPLACER, and ALEKS) and the exact mathematical skill level of a student as assessed by one exam may not have been similarly assess by another exam. Second, this study only used data from one institution which has its own combination of student support structures such as tutoring, peer mentors, and learning strategists which could also influence student success and therefore affecting the generalizability of the results. Finally, at the time of data collection, the new 2-course sequence of developmental mathematics courses was only in place for approximately two years. This time frame limited the sample size which, therefore, may not be representative. The ability to measure any long-term effects of the program change were also inhibited.

Possible threats to validity may also have affected this study and its outcomes. Students who did not enroll in a second developmental mathematics course created an issue of mortality where the outcomes of these students are unknown. The two programs, the pre-redesign 4-course sequence and the post-redesign 2-course sequence, were not offered simultaneously and the passing of time may have had influence on student outcomes. Finally, age, sex, race, attempt number, and sequence length were the only variables used to predict the student success outcomes. Other factors such as Pell grant eligibility, first generation status, and other affective variables were likely confounding constructs that influenced student outcomes.

***Future Research***

The portion of all students at UVU who do not identify their ethnicity is approximately 1%, but the portion was much higher among developmental mathematics students. Almost 20% of the students in the sample of this study did not identify their ethnicity, leading to double analyses for each research question to examine each group separately. The high proportion of students who did not self-identify their ethnicity also limited the understanding of how race impacts student success outcomes for all students. It is possible that students who do not identify their ethnicity would be part of minority populations (Rochon et al., 2004; Wallace & Bachman, 1993), but may not be the case in this instance. Research with this group of developmental mathematics students should be conducted to determine the factors which lead to identifying their ethnicity, particularly why they decline to identify their ethnicity at such higher rates than UVU students as a whole, and how these factors affect other areas of academic performance and success.

Additionally, this study should be repeated when the new 2-course sequence becomes a more routine experience for both faculty and students. This will also provide a larger sample size of post-reform students whose outcomes can then be compared to a larger portion of pre-reform students. The factors included in the analyses should also be expanded to include other demographic variables, such as Pell grand eligibility and first-generation status; cognitive variables, such as high school mathematics GPA and raw placement exam scores; and affective variables, such as family support and self-efficacy levels. Other variables regarding instructional practices of different teachers and their effects could also be incorporated. A repeat of the current study should also involve an exploration of the outcomes of students with the lowest-level placement exam scores who delay their enrollment in the second developmental mathematics course after passing the first course compared to students who immediately attempt the second course. Research of delayed enrollment could reveal useful knowledge about many students including those who pursue other coursework within their major, but especially first-generation students.

Another addition to a future repeat of this study should be the overall progression of students at the lowest mathematical ability levels. This study only used up to two years of post-reform data and could not examine the effect of sequence length on completion of the entire developmental mathematics sequence. This study revealed a lower likelihood of re-enrolling in the second developmental mathematics course after passing the first course. It is possible, however, that a higher percentage of students completed their entire sequence compared to the pre-reform students and should be identified after two and three years of enrollment into their first developmental mathematics course. If so, serious consideration should be made for the students who drop-out between semesters and efforts made to remove obstacles that prevent students from re-enrolling in subsequent developmental mathematics courses. Practitioners should be wary of successful outcomes defined as higher rates of completion as they could be the result of lower-ability students simply removed from the ratio altogether. Other college achievement milestones should also be examined, such as college-level mathematics course outcomes and graduation rates.

Finally, although this study focused on students at the lowest levels of mathematical ability, future studies should include students with higher placement exam scores and their outcomes. Comparisons of the likelihood of re-enrollment into a subsequent mathematics course after passing their first course between lower-level and upper-level placed students may uncover the sources and issues that cause students to drop-out between semesters. The question of which students we are losing in developmental mathematics programs must be asked to determine how to best combat stumbling blocks that students encounter on the path to reaching their potential.

**Conclusion**

Changes in developmental education programs and their structures are almost ubiquitous among higher education institutions and how these changes affect the most vulnerable of students have to be closely monitored. Reactionary or experimental overhauls to programs and courses may not be grounded in strong learning and instructional theory and student success will likely remain stagnant when reforms only involve isolated structural changes, particularly when all students are moved from one rigid pathway through the program to another, equally rigid pathway. Effective developmental mathematics programs clearly show that holistic approaches to the design of programs are what make the difference in the lives of students.

Ultimately, the ideal that educational programs adapt and change to meet students where they are and not according to apparent fads or trends, legislators uninformed of the complexity of education issues, policies made on administrative whims, or complaints of so-called high costs, is not new nor is it radical. Rather, it is the deeply engrained understanding of any teacher in a classroom who works tirelessly to promote authentic learning that all students are unique and that it is the responsibility of practitioners to cultivate an environment where they all can thrive. All students deserve the opportunity to reach their full educational potential regardless of initial ability. The specialists who work in developmental mathematics must advocate for the most vulnerable of students by acting with intention and purpose while endorsing genuine efforts, practices, and designs to improve program elements that are matched to the multi-faceted needs of their students.

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# VITA

Professional Competencies & Capabilities

Highly motivated, results-oriented, proven history of setting and meeting difficult goals and exceeding expectations, works well in a team, strong interpersonal and presentation skills.

Proficiency in multiple statistical software packages, including R and SPSS.

Excellent with students of all ages and levels of mathematical and statistical competence.

Knowledge of Excel, Word, Power Point, Canvas, Blackboard, MyMathLab, Hawkes Online Learning, My Open Math, intellipath, and familiarity with statistical programs such as R and SPSS.

Advanced mathematical and statistical teaching and research skills.

**Teaching Interests Include:** Quantitative Reasoning/Literacy, Statistics, Data Analytics, and Calculus.

**Research and Professional Interests Include:** Adult Learning Theory, Adult Basic Education, Intercultural Inclusive Pedagogy, Assessment of Online and Hybrid Math and Statistics Learning, Overcoming Math and Quantitative Anxiety, and Mathematics Program Outcomes Assessment.

Education

DOCTOR OF EDUCATION ABD (EXPECTED DECEMBER 2021)

DEVELOPMENTAL EDUCATION ADMINISTRATION

*Sam Houston State University* GPA: 4.0 *Huntsville, Texas*

Coursework: Completed Fall 2019.

Comprehensive Exams: Completed Summer 2019

Doctoral Seminars and Coursework Included: Developmental Education & Postsecondary Student, Advanced Learning Theory in Developmental Education, Outcome Assessment in Developmental Education, Designing the Learning Environment in Developmental Education, Academic Writing & Research, Contemporary Issues in Higher Education Leadership and Administration, The College Student, Applied Leadership in Higher Education, Methods of Educational Research, Qualitative Methodology, Teaching Strategies for Developmental Mathematics, Internship in Development Education, Student Noncognitive Development, Statistical Methods for Developmental Education, Strategies for College Reading in Developmental Education

Dissertation (Proposal Defended: October 2020): "The Effects of Acceleration in Developmental Mathematics on Low-Level Placed Students at Utah Valley University": Using a quasi-experimental design and regression analysis to examine the extent to which developmental mathematics program sequence length has an impact on lowest-level placed students' course completion/semester persistence, and grades in developmental mathematics courses, controlling for age, gender, and race/ethnicity.

M.A. IN MATHEMATICS EDUCATION GRADUATED 2011

*Western Governors University Salt Lake City, Utah*

Math content courses included: Calculus and Analysis, Statistics and Probability, Induction/Recursion and Set Theory, Modeling, Number Systems and Number Theory, Euclidean and Non-Euclidean Geometry, Linear Algebra, and Abstract Algebra.

Education courses included: Mathematics Teaching Topics, Mathematics Technology, Mathematics History and Contributions, Mathematics Pedagogy, Capstone Project

B.A. IN MATHEMATICS EDUCATION GRADUATED 2003

*Brigham Young University Provo, Utah*

Math content courses included: History of Mathematics, Ordinary Differential Equations, Survey of Geometry, Statistics and Probability for Education, Fundamentals of Mathematics, Theory of Analysis, Combinatorics, and Abstract Algebra.

Education courses included: Math Teaching in Public Schools, Teaching with Technology, Theory and Methods of Education, Multicultural and Exceptional Education

Academic Employment / Experience

*Part-Time Faculty* *2010-2016, 2017-Present*

Utah Valley University Orem, Utah

Responsibilities: Teach math and statistics courses in the Mathematics Department, Strategy Management and Operations Department, and the Developmental Math Department, including all prep work, lesson planning, assessments, grades, record keeping, and classroom management with 25-30 students per class. Participate in UVU training and professional development activities. Average Instructor SRI: 4.82

*Professor of Mathematics, Lead Faculty* *2020-2021*

American Intercontinental University Online Campus

Responsibilities: Teach mathematics courses in the Department of General Education, including content creation, assessment, grades, and record keeping.

Participate in AIU training and professional development activities. Mentor all other math faculty and conduct math cohort professional development.

*Internship with UVU Math Lab Tutoring Center* *Spring 2019*

Utah Valley University Orem, Utah

Responsibilities: Create a training course to refresh and teach mathematical concepts taught in the college's Quantitative Reasoning (MAT 1030) course to tutors who work with the MAT 1030 students in the Math Lab. I successfully completed an open-education course along with a mini-textbook to facilitate increased levels of preparedness for tutors to help MAT 1030 students achieve success.

*Lecturer* *2016-2017*

Utah Valley University Orem, Utah

Responsibilities: Teach math courses in the Developmental Math Department, including all prep work, lesson planning, assessments, grades and record keeping and classroom management with 25-30 students per class. Participate in UVU training and professional development activities. Average Instructor SRI: 4.88

*Math Tutor* *2016*

Sylvan LearningOrem, Utah

Responsibilities: Tutored struggling students in various levels of mathematics.

*Language Instructor* *2012*

Belarusian State University Minsk, Belarus

Responsibilities: Taught English conversation/grammar/culture courses in the BSU English Language Institute, including coordinating class activities with the Language Institute coordinator and other class leads, all prep work, lesson planning, class activities, and classroom management with 15+ students per class at various levels of English language proficiency.

*Student Teaching* *2003*

BYU/Farrer Middle School Provo, Utah

Responsibilities: Student teacher for 7th grade mathematics classes. Taught Math 7 for low-level math students, Pre-Algebra for average math students, and Algebra Y for excelling math students. This involved all prep work, lesson planning, assessments, grades and record keeping and classroom management for 5 class periods, each with 25-35 enrolled students.

Academic & Professional Service

*Project Read Numeracy Committee Member* *2021 - present*

Project Read, Utah County

Responsibilities: Creation of Adult Basic Education Numeracy Program for Project Read of Utah County. Collaborate with current Project Read Board Members to develop curriculum, assessment, recruitment, and training materials with CCRS standards. Estimated launch of program: Summer 2021.

*Lead Math Professor* *2020 - 2021*

American Intercontinental University

Responsibilities: Serve as mentor to adjuncts/part-time faculty in mathematics, curriculum development, and instructional design. Contribute to AIU training and professional development activities.

*Board of Directors, Conference Poster Chair* *2019 - present*

Utah Academy of Sciences, Arts, and Letters

Responsibilities: Participate in and organize annual academic conference and Awards Night. Organize Poster Session for annual conference and facilitate communication with discipline specific board members and poster applicants.

*Curriculum Committee Member* *2016 - 2017*

Developmental Math Department, UVU

Responsibilities: Begin initial curriculum development for an accelerated, two-course sequence in developmental mathematics through identification and elimination of repeated content, collaboration with Department of Mathematics to define necessary prerequisite objectives and organize and assign content objectives to appropriate courses.

Awards

UVU Part-Time Faculty Member of the Year, Wolverine Achievement Awards, 2013-2014

Scholarly & Practitioner Publications

"The Effects of Acceleration in Developmental Mathematics on Low-Level Placed Students at Utah Valley University." – Dissertation, in progress.

"Coaching, Mentoring and Training Employees: Utilizing Foundational Learning Theories and Inclusive Pedagogy." *Employee Learning and Development Excellence*, *HR.com*, July 2021.

"Student Learning Motivation, and Application to Interculturally Inclusive Pedagogy." *The International Journal of pedagogy and curriculum*, forthcoming publication.

"Enhancing Women Empowerment in the Workplace." *Leadership Excellence*, Vol. 37, Issue 11, 2020.

“Assessing the Effectiveness of Hybrid Course Design and Student Learning Outcomes in Management and Math Courses.” *Journal of the Utah Academy of Sciences, Arts, and Letters,* Vol. 91, p. 69-89, 2015.

*Engaging Hybrid and Blended Learning in Higher Education* (ed). Champaign, IL: University of Illinois Press (e-Learning and Innovative Pedagogies Series), 2014.

"Hybrid Course Design Assessment." In *Engaging Hybrid and Blended Learning in Higher Education.* Champaign, IL: University of Illinois Press (e-Learning and Innovative Pedagogies Series), 2014.

"Engaging Instructional Design in the Developmental Mathematics Classroom: Assessment, Reflections, and Future Directions." *International Journal of Pedagogy and Curriculum,* Vol. 19, Issue 1, p. 21-35, 2014.

"Teaching Hybrid Courses across Disciplines: Effectively Combining Traditional Learning and e-Learning Pedagogies." *International Journal of Information and Education Technology*, Vol. 4, Issue 1, p. 93-96, 2013.

Academic Conference Presentations

“The Effects of Acceleration in Developmental Mathematics on Lowest-Level Placed Students at Utah Valley University.” Innovative Research Panelist, *College Reading and Learning Association Annual Conference (Virtual)*: November 2020.

“Student Learning Motivation, and Application to Interculturally Inclusive Pedagogy.” *Annual Teaching 4 Learning Conference (Provo, UT):* March 2020.

“Foundational Learning Theories and Student Learning Motivation.” *International Conference on Education and Social Science for the International Academy of Science, Technology Engineering and Management (Rome, Italy):* October 2018.

“Adjuncts in Developmental Mathematics Education.” *Annual Conference for Utah Mathematical Association of Two Year Colleges (Salt Lake City, Utah):* October 2018.

“Classroom Assessment and Classroom Research.” *Annual Conference for Southwest Association for Developmental Education (Orem, UT):* October 2018.

“Assessing the Effectiveness of Hybrid Course Design and Student Learning Outcomes in Management and Math Courses.” *Annual Conference of the Utah Academy of Sciences, Arts, and Letters (St. George, UT):* Panel Session—Business, April 2014.

“Teaching Hybrid and Blended-Learning Courses across Disciplines: Developmental Math and Human Resources Management." *UVU 6th Annual Scholarship of Teaching and Engagement Conference (Orem, UT)*: March 2014.

“Teaching Hybrid Courses across Disciplines: Effectively Combining Traditional Learning and e-Learning Pedagogies." *International Conference on Distance Learning and Education (Paris, France)*: October 2013.

"Engaging Students in Developmental Math." *Scholarship of Teaching and Engagement Annual Conference (Orem, UT):* Panel Session—Engaged Teaching, March 2013.

"Engaging Instructional Design in the Developmental Mathematics Classroom: Assessment, Reflections, and Future Directions." *International Conference on Learning (London, UK):* Panel Session—Maths, Science, and Technology learning, August 2012.

"Assessing Effective Instructional Design in the Developmental Mathematics Classroom." *Annual Conference of the Utah Academy of Sciences, Arts and Letters (Salt Lake City, UT):* Panel Session—Education, April 2011.

"Increasing Developmental Math Students' Success through Engagement and Collaboration." *Scholarship of Teaching and Engagement Annual Conference (Orem, UT):* Panel Session, March 2011.

Invited Presentations / Trainings

Westover, Jacque P. 2019. "Building Open Education Training Tools for Math Lab." *UVU Math Lab (Orem, UT)*, August 14.

Westover, Jacque P. 2018. "Student and Teacher Communication." *UVU Department of Communication, Executive Lecture Series (Orem, UT),* September 24.

Bye, Colleen; Arendt, Anne; and Westover, Jacque P. 2013. "Engaging Students in Developmental Math." *Development Math Department Faculty Training Workshop (Orem, UT),* March 18.

Westover, Jacque P. 2013. "Reflections on an International Fulbright Experience with the Family." *Variette Club (Payson, UT)*, February 7.

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