BRIDGING THE GAP: EFFECTS OF DUAL CREDIT COLLEGE ALGEBRA ON POSTSECONDARY EDUCATION OUTCOMES

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DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education at the University of Kentucky

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ABSTRACT OF DISSERTATION

BRIDGING THE GAP:
EFFECTS OF DUAL CREDIT COLLEGE ALGEBRA ON POSTSECONDARY EDUCATION OUTCOMES

The contraction of the blue-collar economy is slowly rendering the high school diploma obsolete as an entry-level requirement for middle class employability. Over the last 40 years, jobs requiring some sort of postsecondary education or post-high school credential increased from 28% to 62%, while lower-skilled jobs, traditionally filled by high school graduates or those without a high school diploma, decreased from 72% to 38%. As automation slowly replaces the blue-collar workforce, it is critical that our educational system provides all students the necessary tools to successfully complete a postsecondary degree or credential.

This study examined two groups of graduating high school seniors and longitudinally followed their postsecondary progress and completion. One group was comprised of students who had taken dual credit college algebra their senior year and the second group consisted of students who had not taken dual credit college algebra at any time during high school. Because enrollment in dual credit college algebra at most postsecondary institutions required a math ACT subscore of 22 or higher, each group was further divided into two subgroups consisting of students with a junior ACT math subscore < 22 and students with a junior ACT math subscore ≥ 22.

Propensity score matching was used to match dual credit college algebra takers with their similar non-participating peers using student senior academic year, gender, race & ethnicity, free/reduced lunch status, school Title 1 status, school census size, final high school GPA, and English and math ACT subscores as covariates. Propensity score matching was followed by linear regression analysis examining the relationship between dual credit college algebra taking and postsecondary enrollment immediately following graduation, first year postsecondary persistence and GPA, time to degree, credential and degree completion and attainment of a STEM or math/technology competency degree. The results of this study showed significant gains for the < 22 ACT math group in postsecondary enrollment, first year GPA, time to degree, and bachelor degree completion. The results for students in the ≥ 22 math ACT group showed significant gains in postsecondary enrollment and time to degree.

Based on the results of this study, implications for educational practice are twofold. First, secondary and postsecondary institutions should work together to increase the support and opportunities for underprepared students to participate in rigorous dual credit coursework, including dual credit mathematics courses. Secondly, high stakes placement exams and ACT/SAT benchmarks need to be replaced with multiple measures instruments measure more than just content assimilation for dual credit college algebra.

This study was limited by the absence of a randomly chosen control group, a lack of standardization in data collection and missing postsecondary data from private and out of state postsecondary institutions. It is hoped that this study inspires further research on dual credit college algebra on its effect on postsecondary outcomes. A qualitative study investigating student motivation, academic confidence, self-efficacy and other affective variables would help to better identify the positive effects of dual credit course taking on underprepared students, which in turn could encourage improved dual credit programming.

KEYWORDS: Dual Credit, College Algebra, College Ready,
Underprepared, Postsecondary

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August 7, 2020

Date

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To my grandkids Bella, CJ, and Mason. I pray you develop a passion for learning, a love for service and a desire to champion those less fortunate than yourselves.

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The Challenge

The contraction of the blue-collar economy is slowly rendering the high school diploma obsolete as an entry-level requirement for middle class employability (Hoffman, Vargas, Venezia & Miller, 2007). Over the last 40 years, jobs requiring some sort of postsecondary degree or post-high school credential increased from 28% to 62%, while lower-skilled jobs, traditionally filled by high school graduates or those without a high school diploma, decreased from 72% to 38% (Carnevale, Smith, & Strohl, 2010). According to the Bureau of Labor and Statistics Spotlight report (2010), over the past two decades, the largest increase in employment has been among those with at least some postsecondary education, primarily those with a bachelor’s degree

As automation slowly replaces the blue-collar workforce, Carnevale, Smith, & Melton, (2011) project a significant increase in demand for qualified workers in STEM fields (science, technology, engineering and mathematics) including scientists, engineers, mathematicians, technicians in advanced manufacturing and other technology- driven industries. Of even greater concern is the insufficient supply of workers with math and technology (MT) competencies needed to fill quickly expanding industry positions in areas of business, management and healthcare services (Thiel, Peterman, & Brown, 2008). Future employees seeking to be part of the middle class economy will need to attain a postsecondary degree or some sort of post-high school credentialing to possess the ever increasing level of mathematics dependability, technology literacy, content knowledge, and problem-solving skill needed for continual learning and the capacity to function in an environment of constant innovation and technological change (American College Test, 2018; Aoun, 2017; Carnevale, Smith, & Melton, 2011).

The increase in postsecondary tuition has become an obstacle for many attempting to gain a postsecondary education, and time limit restrictions attached to federal financial aid a barrier to degree completion (https://www.epcc.edu/Admissions/FinancialAid/eligibility). Legislation recently passed by Congress limits the number of credit hours for which a student may receive federal financial aid assistance to a calculated Lifetime Eligibility Used (LEU) percentage, which is 150% of the published length of the educational program (https://studentaid.ed.gov/sa/types/grants-scholarships/pell/calculate-eligibility#how-calculated). This new legislation has specific implications for those seeking STEM degrees. Since STEM degrees usually include several sequenced math courses, students wishing to enter a STEM field must complete their math courses, in sequence, within the allowed financial aid timeline or be forced to change majors or drop out. Clearly, insufficient secondary mathematical preparation can negatively impact postsecondary persistence and successful degree completion in lucrative career fields.

Another barrier to postsecondary degree attainment is the lack of collaboration and alignment between secondary and postsecondary institutions (Adelman, 2004). Postsecondary success has been directly linked to adequate high school preparation, hence it is imperative that secondary and postsecondary institutions work together to improve academic preparation if graduates are to meet the demands of highly technical 21st century careers (Adelman, 2006; Bound, Lovenheim, & Turner, 2010; Hoffman, Vargas, Venezia, & Miller, 2007; Hoyt & Sorenson, 2001).

Secondary graduation requirements, course pathways, and assessments of academic preparation vary by state and district, however, a majority of institutions continue to use the American College Test (ACT) and the Scholastic Aptitude Test (SAT) as significant indicators of student preparation and/or college readiness (Qiu, Wu, 2010). According to the ACT Condition of College and Career Readiness (2018), 38% of high school graduates from across the country met three of the four core subject area ACT College Readiness Benchmarks and the number of students who met none of the benchmarks increased from 33% to 35%. Of the students tested in 31 out of 50 states, fewer than half met the individual college readiness benchmarks for reading, math, or science.

Several studies have found secondary course-taking patterns to be a more robust measure of college readiness and predictor of postsecondary academic success, and of courses in the secondary curriculum, completion of intensive high school mathematics courses was found to have the strongest effect on postsecondary degree completion regardless of major (Adelman, 1999, 2004, 2006; Boser & Burd, 2009; Bozick, & Ingels, 2008; Park, Woods, Hu, Jones, Tandberg 2018; Trusty & Niles, 2003). In a study conducted by the National Center for Education Statistics (2008), gains in math proficiency were correlated with low, medium, and advanced math course sequencing where Algebra II, Precalculus and above were considered advanced level mathematics. Large overall gains in math achievement and college readiness were reported for students who followed a math course sequencing of Algebra 1 and Algebra II, Geometry, Trigonometry, and other advanced mathematics during the last two years of high school, compared to students who stopped at geometry (Adelman, 2006; Bozick & Ingels, 2008; Noble & Schnelker, 2007). It is obvious that rigorous secondary course taking needs to be an integral part of high school preparation for students pursuing a postsecondary education, particularly in math, which is a critical core content for postsecondary success and middle-class employability.

A third positive association was reported between dual credit (DC) participation, also known as concurrent enrollment (CE), and postsecondary success (An, 2013; Karp, Bailey, Hughes, & Fermin, 2007; Morrison, 2008). Dual credit courses are designed to provide high school students with the opportunity to enroll in credit-bearing college coursework and concurrently receive college and high school credit for the same course (Tobolowsky & Allen, 2016). Significant effects were found between DC participation and postsecondary outcomes and on average, holding ACT score, gender, income, race, and ethnicity constant, concurrently enrolled students had a 22.9 percent increase in the likelihood of enrolling in college immediately after high school graduation and an 11.2 percent reduction in developmental course enrollment (Bautsch, 2014; Giani, Alexander & Reyes, 2014). The U.S. Department of Education, What Works Clearinghouse (2017) found participation in dual credit programs had positive effects on postsecondary degree attainment, college access and enrollment, credit accumulation, high school completion, and secondary academic achievement.

According to Karp, Bailey, Hughes & Fermin, (2004), equal access to dual credit coursework presents a continuing problem, with many state policies and postsecondary institutions requiring a high level of academic skill for participation in dual credit, particularly dual credit college algebra (An, 2013). Since the eligibility criteria for secondary student dual credit enrollment tends to mimic the requirements for postsecondary student enrollment, standardized test scores play a significant role in restricting access to dual credit course taking with high-achieving students the primary recipients of dual credit programming (An, 2013; Bailey & Karp, 2003; Karp, Bailey, Hughes & Fermin, 2004; Giani, Alexander & Reyes, 2014; Ozmun, 2013). However, it is important to note that ACT and SAT college readiness benchmarks were created from data analysis preformed on postsecondary student outcomes and not secondary student outcomes (Zwick, 2002). Because secondary and postsecondary are separate systems with different accountability metrics, expectations and institutional cultures, more research needs to be done specifically examining the relationship between ACT/ SAT performance and dual credit course taking outcomes (Conley, 2007; Hoffman, Vargas, Venezia., & Miller, 2007).

In an effort to improve the passing rate of underprepared first-time freshmen in credit-bearing math and English courses, postsecondary institutions often require undergraduates not considered college ready to first complete developmental education (DE) coursework (The Phipps, 1998; Kozeracki, 2002). DE courses which are non-credit-bearing and do not count toward degree attainment, are designed and intended to remediate skill deficits in math, reading, and/or English, ultimately leading to increased success in subsequent credit-bearing coursework (Bahr, 2010; Ganga, Mazzariello, Edgecombe, 2018). According to the ACT (2016, 2017, 2018, 2019) more than half of first-time undergraduates from all over the country arrive on postsecondary campuses underprepared for credit bearing coursework. Results from the NELS:88 survey found approximately 60% of first-time college freshmen at public two-year institutions and 30% at public four-year institutions were underprepared for college- level coursework and were subsequently enrolled in at least one developmental course, with math remediation more common than English/reading remediation (Adelman, 2004; An, 2013; Attewell, Lavin, Domina, & Levey, 2006; Kozeracki, 2002). Similarly, the 2004/09 Beginning Postsecondary Students Longitudinal Study (BPS:04/09) and its associated 2009 Postsecondary Education Transcript Study (PETS:09) reported 70% of first-time college freshmen at public two-year institutions and 40% at public four-year institutions were enrolled in at least one developmental course with the proportion of students enrolling in developmental math coursework twice that of English/reading at two-year public postsecondary institutions and three times as high at public four-year institutions. (Chen, 2016).

The assumption that students enrolled in DE courses would eventually pass their credit bearing general education coursework is not supported by results from the BPS:04/09 and PETS:09 (Chen, 2016). General education (GE), also known as gateway courses, are defined as first-year, entry level, credit-bearing courses, required for undergraduate degree attainment at postsecondary institutions, particularly four-year degree programs (Chen, 2016; Thiel, Peterman, & Brown, 2008). Chen (2016) found that nationally fewer than 50% of DE students successfully completed their DE coursework at two-year public postsecondary institutions and approximately 60% completed their DE coursework at four-year postsecondary institutions. Moreover, DE math completion rates were substantially lower than those of English or reading and among the DE completers only 31% earned GE math credits, compared to 49% earning GE English credits after six years. Partial DE completers and non-completers were even less successful, with only 12% and 3% respectively eventually earning GE math credit. In summary, fewer than half of enrolled DE students successfully earned GE math credit and a little more than half earned GE English credit.

With fewer than half of the underprepared students from the BPS:04/09 and PETS:09 study earning college-level math credit, it can be surmised that unsuccessful completion of required GE math courses is a substantial impediment toward two- and four-year degree attainment (Chen, 2016). The number of underprepared DE students who attained to an associate (16%) or bachelor's degree (7%) at two-year institutions within 6 years was disturbingly low. Clearly, underprepared students at both two and four-year public institutions struggle to pass college-level, credit bearing math courses. In fact, course failure rates are higher for GE statistics and college algebra courses than for any other academic discipline, and a fear of math or lack of confidence can delay enrollment in these courses, which in turn delays time to a degree (Gupta, Harris, Carrier, & Caron, 2006; Thiel, Peterman, & Brown, 2008).

Although remediating academic deficits at the postsecondary level does provide success for some students, critics feel it is not efficient or cost effective for far too many, a waste of taxpayer money, and an unreasonable financial burden for the large number of students who ultimately do not graduate with the benefit of a degree (Adelman, 2004; Attewell et al, 2006; Bahr, 2010; Kozeracki, 2002; Merisotis & Phipps, 2000). Proponents of DE programs argue that they increase diversity, educational opportunity, and degree attainment for underprepared students, which has societal and monetary consequences since students with a postsecondary degree are more likely to be part of the middleclass workforce, have a higher quality of life, and make positive societal and monetary contributions (Bahr, 2010; Kozeracki, 2002; Merisotis & Phipps, 2000). The question becomes whether postsecondary remediation is the most effective intervention for the large number of underprepared secondary graduates pursuing a postsecondary degree.

Perhaps, instead of remediating students at the postsecondary level, solutions to low degree attainment and insufficient preparation should be focused on improving secondary preparation, aligning high school and postsecondary curriculums, standards, assessment criteria, and expectations for college and work as well as increased intensity of high school preparation, early intervention, improved quality of the learning environment, mentoring, tutoring, advising, and improving teacher preparation at the secondary level. (Aldeman, 2006; Hoffman, Vargas, Venezia., & Miller, 2007; Merisotis and Phipps, 2000).

The Intervention

In order to increase the number of students successfully earning college-level credit and completing a 2 or four-year degree in fields requiring math competency, educators at all levels need to find a way to better prepare secondary students for college level math content. Interventions which prepare all students for rigorous college coursework, providing access and exposure to college-level math content, culture and expectations, must be in place before secondary students matriculate to postsecondary institutions. What would be the longitudinal impact on postsecondary outcomes if high school students could enroll in dual credit college algebra without the limitations of standardized test scores or other prerequisite requirements other than a C in algebra II and secondary staff recommendations? Would increasing secondary preparation and access to college level mathematics impact persistence as well as choice and successful completion of a postsecondary degree/credential? Furthermore, can preparation and completion of a credit bearing college algebra course in high school predict student persistence to degree and successful completion of a STEM or MCB degree/credential? These are the educational issues that motivate this study.

Definitions

This study explores many educational concepts and issues. This section is intended to provide the necessary background information. *General education* or *gateway math courses* refers to first-year, entry-level, credit-bearing coursework such as college algebra, statistics, or some similar required gateway math course. *Remediation* refers to the process of improving academic skills for underprepared students that are foundational to learning, such as those used in mathematics, reading, and writing through developmental coursework. (Phipps, 1998; Kozeracki, 2002; Levin & Calcagno, 2008). *Developmental education (DE)*, often used interchangeably with remedial education, refers to courses that receive institutional credit but do not carry college credit that counts toward degree completion, lack college level content and are required as prerequisite courses for college credit-bearing courses (Chen, 2016).

High school grade point average (GPA) refers to the GPA of a high school student upon graduation. *College readiness* refers to a predetermined level of preparation for college math and English, often determined by standardized test scores, such as the ACT/SAT and high school GPA. *ACT/SAT Band*s refers to standardized test score groupings that are used by many postsecondary institutions to determine college readiness and to refer students. *Credit-bearing courses* refer to courses that contain college-level content and award college credit toward degree completion. *Passing grade* refers to a grade of A, B, C or P. As defined by the 2018 U.S. census, *metropolitan* statistical area refers to a county associated with at least one urbanized area of at least 50,000 residents, plus adjacent counties with high social and economic integration; *micropolitan* refers to a county associated with at least one urban cluster between 10,000 and 50,000 residents, plus adjacent counties with high social and economic integration; and *rural* refers to an isolated statistical area with a population of less than 10,000 and no social and economic integration with an urbanized area or cluster (https://www.census.gov/programs-surveys/metro-micro/about/glossary.html).

Postsecondary institution (PSI) refers to a college or university offering a four-year bachelor's degree or community college offering a two-year degree. *First-time freshman* refers to a student enrolling at a postsecondary institution for at least 12 hours of coursework the semester following graduation from high school. *Postsecondary enrollment and Matriculation* refer to full-time enrollment at a 2 or four-year university as a first-time freshman. *First-year persistence* refers to a first-year freshman enrolling in 12 credit hours or more for at least two terms plus summer (but excluding winter intercession) of their freshman year. *Second-year persistence* refers to student enrollment at a postsecondary institution for 12 credit hours or more for at least two terms plus summer (but excluding winter intercession) of their sophomore year. *Persistence by year* refers to the number of consecutive semesters a student registers for at least 12 credit hours. *Persistence to degree* refers to attainment of a postsecondary 2 or four-year degree graduation within four or six years, respectively. *Dropout* refers to students who stop attending a postsecondary institution for several years and/or never return to complete their degree. *Stopout* refers to students who cease attending their college or university for one or two consecutive semesters or years at a time but eventually return to complete a degree.

Research Questions

This study aims to address two groups of research questions pertaining to the effects of access to college-level mathematics in high school on participation and performance in postsecondary education:

1. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT Math score, and high school demographics, does enrollment in a dual credit college algebra course during high school increase the likelihood of enrollment immediately following graduation in both two-year and four-year postsecondary education?
2. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT Math score, and high school demographics, does enrollment in a dual credit college algebra course during high school affect the following:
    a. Postsecondary first-year persistence?

b. Postsecondary first-year GPA?

c. Postsecondary time to degree and degree completion

d. Degree attainment in a STEM or math/technology competency-based field?

The Significance of This Study

First, this study makes an important contribution in analyzing the relationship between student participation in dual credit college algebra and postsecondary outcomes. Specifically, this study examines the longitudinal impact of allowing high school students to enroll in a credit-bearing college algebra course requiring only a C in Algebra II as a prerequisite. Inspired by the 1985 Stanford study conducted by Uri Treisman, “Access to Algebra” (A2A) students were invited to participate in college algebra coursework traditionally closed to them (Fullilove & Treisman, 1990). The A2A college algebra program examined in this study is a continuation of the A2A program began at The University of Kentucky in 2006 and funded by a National Science Foundation (NSF) grant as part of the Appalachian Mathematics and Science Project (AMSP). The University of Kentucky A2A college algebra program was designed to offer rural high school students’ access to dual credit college algebra.

Placement criteria is not standardized and differs somewhat between postsecondary institutions, but in general, students enrolling in public state postsecondary institutions in Kentucky must have an ACT math subscore of 22 or higher. Although, the statewide ACT math benchmark for college readiness is listed as 19 or above, matriculating undergraduate students with ACT math subscores < 22 are considered mathematically unprepared to successfully enroll in college algebra at the postsecondary level. In 2014, many Kentucky two and four-year public postsecondary institutions began offering accelerated/co-requisite college algebra coursework to students with ACT math subscores between 19 and 22, inclusive, which provides students with increased in-class contact hours, seminars, and other additional supports (http://cpe.ky.gov). These modified college algebra courses are primarily for on-campus postsecondary undergraduates and currently not available to dual credit students. If accelerated/co-requisite college algebra is not available for dual credit students, then students not in the A2A college algebra program must have a math ACT subscores of 22 or above to enroll in dual credit college algebra. Matriculating undergraduate students with ACT math subscores < 19 are referred to either a developmental or prerequisite credit-bearing math course prior to enrollment in an accelerated/co-requisite college algebra. Kentucky, along with several other states, has recently passed legislation shifting the enrollment of underprepared students in need of developmental education from four-year public institutions to two-year community colleges (http://cpe.ky.gov/policies/academicaffairs/admissionsfaq.pdf; Parker, 2007).

This study will investigate the longitudinal impact on postsecondary outcomes of exposing mathematically high school underprepared students (ACT math subscores less than 22) to the rigor and expectations of a college algebra curriculum. The results of this study will offer significant measurable benefits, provide important insights for educational practices and inform dual credit policy, early college programs, secondary/postsecondary collaborations and college preparation programs. Secondly, this study may directly inform policies and programs designed to increase the STEM and MTC based workforce in the state of Kentucky.

Finally, this study may have critical educational implications with respect to equity and access of educational opportunities as racial and economic disparities in postsecondary preparation and subsequent remedial course enrollment continue to be well documented (Adelman, 2004, 2006; Bahr, 2010; Chen 2016). Insufficient secondary preparation often leads a larger percentage of students from minority and low SES groups to be placed into developmental courses and, consequently, increases the likelihood that they will dropout or stopout before completing a degree (Bahr, 2010; Chen 2016). The short-term effects of participation in A2A on college readiness and academic factors, which include ACT, HSGPA, first year postsecondary GPA, choice of major, first and year persistence and performance, will be analyzed. The long-term effects studied are second- year persistence, degree choice and impact on persistence to degree.

Finally, this study will seek to determine if exposing underprepared high school students with ACT math subscores less than 22 (or SAT equivalent) to the rigor and content of a college algebra curriculum while still in high school has a significant effect on the overall academic success of their first-year of post-secondary education, first-year persistence, persistence to degree and degree choice. This information has important implications to educational policies.

The Organization of This Study

Chapter 1 provides an overview of the problem and one solution in which this study aims to engage. Chapter 2 examines the literature on postsecondary mathematic course enrollment patterns, passing rates, high school preparation, developmental, and corequisite course taking patterns and success rates, credit-bearing pass rates in mathematics, the number of students pursuing a STEM degree, and the impact on underrepresented minorities. The impact of dual credit courses on postsecondary success is also examined. Chapter 3 explains the methodology and statistical design used to analyze the research questions. Chapter 4 reports the results of the research analysis. Chapter 5 discusses the impact and ramifications of the results, conclusions, and implications of the research results.

Chapter 2: REVIEW OF THE LITERATURE

21st Century Employment and the Role of Postsecondary Education

In 1967, approximately 70% of middle-class families were headed by high school graduates with no postsecondary education, and by 2004 that number had decreased to less than 50% (Hoffman, Vargas, Venezia., & Miller, 2007). According to the Georgetown University Center on Education and the Workforce Projections of Jobs and Education Requirements (2010), workers with a postsecondary education have access to multiple middle-class and high-end occupational clusters across the economic spectrum, with the largest number of postsecondary workers concentrated in five job clusters: STEM, education, healthcare professional and technical, community services and arts, and managerial and professional office occupations. Workforce projections over the next 10 years predict the number of jobs requiring a postsecondary degree will increase from 59% to 63%, and newly created job markets and industries, combined with a steady flow of retiring baby boomers, will continue to generate high-paying jobs for future college graduates (Carnevale, Smith, & Strohl, 2010). Current postsecondary enrollment, persistence, and graduation data predict that there will be a shortage of college graduates to fill positions vacated by retirees (Carnevale, Smith, & Strohl, 2010; Hoffman, Vargas, Venezia & Miller, 2007).

In contrast, nine out of 10 workers with no postsecondary education or credential are limited to a small subset of three low-paying, low-skill occupational clusters (food and personal service, sales and office support and traditional blue-collar jobs) that are slowly disappearing (Carnevale, Smith, & Strohl, 2010). Workers filling these low-skill jobs are under an ever-increasing threat of being replaced by robotics and computer-assisted technology (Aoun, 2017; ACT, 2017; Carnevale, Smith, & Strohl, 2010).

The Pew Research Center's analysis of government jobs data in *The State of American Jobs* (2016) documented several findings concerning employment and job growth based on the level of education preparation. Preparation levels included high school degree only, mid-level education preparation, identified as having an associate degree or post-high school credential, and high-level education preparation, identified as completion of at least a four-year degree. The center reported an average of 50% employment growth in multiple occupations from 1980 to 2015, with the highest growth (83%) taking place in jobs requiring high social skills, such as communication or management skills, and 77% growth in jobs requiring higher levels of analytical skill, such as critical thinking and computer proficiency. In addition, high job growth was recorded for careers requiring a combination of strong social and analytical skills compared to jobs requiring high levels of physical or manual skill, which at 18% had relatively little growth. Furthermore, from 1980 to 2015 employment for mid-to-high-level preparation and education increased by 68% from 49 million to 83 million jobs. compared to an increase from 50 million to 65 million (31%) for jobs requiring low-level job preparation and education.

Carnevale, Smith, & Melton (2011) found the demand for workers in STEM increased the need for workers with a postsecondary education at all levels, including credentialing, associate, and bachelor's degrees. They also reported shortages in the STEM workforce including scientists, engineers, mathematicians, and technicians in advanced manufacturing and other technology-driven industries. Of even greater concern was the insufficient supply of workers with math and technology (MT) competencies (mathematical proficiency and technological literacy) needed for quickly expanding industries such as professional office and business services and healthcare services (Carnevale, Smith, & Strohl, 2010; Thiel, Peterman, & Brown, 2008). Dramatic increases in automation and new technologies in these industries require workers with MT competencies who possess not only content knowledge but processing and problem-solving skills, which support continual learning and the ability to function in an environment of constant innovation and technological change (ACT, 2018; Aoun, 2017; Carnevale, Smith, & Melton, 2011).

Clearly, mathematics proficiency combined with postsecondary credential/degree attainment is important for current and future employability. One of the barriers to postsecondary degree attainment is the misalignment between secondary and postsecondary institutions, which leaves many high school graduates insufficiently prepared for college level course work (Conley, 2007; Hoffman, Vargas, Venezia., & Miller, 2007). Underprepared students lacking the necessary mathematical proficiency needed to earn college-level math credits are largely unaware that their chances of attaining a two- or four-year degree are less than 50% (Aldeman, 2006; Chen, 2016). Students pursuing a post-secondary two- or four-year degree are required to take at least one college level general education (GE) math course, with many degree pathways – particularly STEM fields – necessitating a passing grade of C or better in an algebra-based course, such as college algebra (Chen, 2016; Herriott & Dunbar, 2009). This requirement creates a serious academic barrier for students who begin their post-secondary education underprepared to successfully pass a college-level math course. Chen (2016) found that 59% of students at two-year and 33% at four-year public postsecondary institutions lack the proper mathematical background to be considered college ready in math and are assigned to at least one developmental education (DE) math course. He also found that fewer than 50% successfully complete their DE math course(s) and earn college-level credit in their subsequent GE math course. Consequently, access to college level-math coursework, including college algebra, is hindered, which in turn thwarts efforts to supply the workforce with STEM and MT competency-based professionals (Ganga, Mazzariello, Edgecombe, 2018; Thiel, Peterman, & Brown, 2008).

Time can also be a barrier for those underprepared to attain a postsecondary degree. Students must complete a postsecondary undergraduate degree within their calculated student loan credit hour Lifetime Eligibility Used (LEU) percentage (150%) specified by the federal government (https://studentaid.ed.gov/sa/types/grants-scholarships/pell/calculate-eligibility#how-calculated). For example, a financial aid LEU for a 60-hour two-year degree is 90 hours, and a 120-hour, four-year degree is 180 hours. Once students exceed their LEU percentage, they are no longer eligible to receive federal financial aid. Graduating high school students seeking a postsecondary degree or credential must be well prepared in order to complete their degree within the specified financial aid limitations. Underprepared students are too often placed in postsecondary developmental math and English courses, where completion rates for students in these courses can add up to a year or more of noncredit-bearing coursework hindering postsecondary education and degree attainment (Adelman,1999; Bahr, 2010; Bettinger and Long, 2004; Bailey, Jeong, & Cho, 2010; Calcagno, Crosta, Bailey, Jenkins, 2007). Students without private means who are unable to complete a degree or credential within the allowed financial aid timeline might be forced to change majors or drop out.

If students stop out or drop out of college, they are required to pay back any financial aid debt they have accrued. Students leaving before earning a postsecondary degree or credential who find their employment opportunities limited to low-skill, low-wage jobs, will find it difficult to pay back their student loan debt (Carnevale, Smith, & Strohl, 2010). According to the U.S. Department of Education, Office of Federal Student Aid, the number of direct student loans entering default rose from $4.65 billion in 2014 to $8.53 billion in the third quarter of 2019

(https://studentaid.ed.gov/sa/about/data-center/student/default). If their student default rates exceed the threshold allowed by the U.S. government, postsecondary institutions will be forced to choose between limiting student access to only the well prepared or risk losing federally funded student aid dollars.
(https://www2.ed.gov/offices/OSFAP/defaultmanagement/definitions.html).

Recent change in federal student loan policies could have further implications for students seeking a postsecondary degree. Student loan policies combined with insufficient mathematical preparation clearly can have a negative impact on postsecondary persistence and successful degree attainment for underprepared students, particularly those wishing to pursue a degree that requires multiple sequenced, college credit-bearing math courses. If a postsecondary degree is the bridge to middle-class employability, then insufficient math preparation is the troll hiding under the bridge. Educators must find a way to better prepare students for credit-bearing postsecondary math coursework, the successful completion of which is essential for degree attainment and meaningful employment opportunities.

Postsecondary Preparation and Persistence

The National Center for Education Statistics (NCES) analyzed data from the High School Longitudinal Study of 2009 (HSLS/2009), which collected data on a nationally representative cohort of ninth-grade students in 2009. The U.S. Department of Education Annual Report, *The Condition of Education 2019*, summarized NCES educational findings from 2000 to 2017, including postsecondary education and employment outcomes (McFarland et al., 2019). Outcomes reported include enrollment rates, types, and number of degrees awarded, and differences in salary, employment, and unemployment based on degree attainment. Both postsecondary enrollment and degree attainment increased from 2000 to 2017, although a large percentage of first-time students who enrolled at a postsecondary institution did not complete a degree or credential. The combined postsecondary enrollment rate for students ages 18 to 24 increased from 35% to 40%. In 2017, the “immediate” enrollment rate (enrollment by October following secondary graduation) of first-time freshmen was 67% at four-year institutions and 44% at two-year institutions. Immediate enrollment rates increased for White (65% to 68%) and Asian students (73% to 87%), with the most notable increase coming from Hispanic students (49% to 67%). However, no measurable increase was found for African American students (57% to 58%). Approximately 62% of first-time freshmen were retained and returned in the fall of the following year at two- and four-year public institutions. Of the first-time two-year undergraduates who began their postsecondary education in 2014, approximately 32% attained an associate degree or certificate within 150% of the normal hours needed for a degree (about three years). At four-year institutions, 60% of students graduated with a degree within 150% of the normal hours (six years) required for a degree. The percent of STEM degrees awarded at two- and four-year institutions was 8% and 19%, respectively. At both institutions, Asians and nonresident aliens were much more likely to attain a STEM degree than other graduates. McFarland et al (2019) felt that increased student enrollment cannot be considered a successful measurement when such a large number of students graduate with financial aid debt and without earning a degree or credential.

This is particularly worrisome in light of the substantial differences reported by the U.S Department of Education Annual Report in full-time, full-year employment, earnings, and lowered unemployment rates associated with degree attainment (McFarland et al., 2019). Between 2010 and 2017, the percentage of young adults with full-time, year-round employment increased for every level of educational attainment except for those with some college but no degree. Those with some college but no degree actually lost ground in full-time, year-round employment, from 72% in 2000 to 69% in 2017. Full-time employment for high school completers increased from 60% to 71% compared to associate degree completers (67% to 73%) and bachelor's degree holders (74% to 78%). It is worth noting that master's degree holders did not have noticeably higher full-time employment percentages (74% to 77%) than bachelor's degree holders.

Similarly, median earnings were higher at all levels of degree attainment. McFarland et al. (2019) continued to report that median earnings of high school completers were 23% higher ($32,000) than non-high school completers ($26,000). Earnings of bachelor's degree holders were 62% higher ($51,800) than high school completers, and master's or higher degree median earnings ($65,000) were approximately 26% higher than bachelor's degree earnings. Furthermore, employment rates were consistently higher for all levels of degree attainment at 59%, 72%, 79%, and 86%, respectively for high school non-completers, high school completers, some college but no degree, and bachelor's degree or higher. Likewise, unemployment rates were lower for young adults based on degree attainment decreasing from 9% for high school non-completers to 2% for those completing a bachelor's degree or higher. Overall, the benefits of postsecondary degree attainment are substantial and well documented (McFarland et al, 2019).

Callan, Finney, Kirst, Usdan & Venezia (2006) point out the fastest-growing demographic sectors in the population are low income and minority groups who are underserved at all levels of P -16 education, yet they hold a majority of low-skilled jobs and are significantly less likely to attain a postsecondary degree. In fact, approximately 65% of students at the lowest level of socioeconomic status (SES) earn a high school degree compared to 91% of students in the middle and above range (Goldberger, 2007). Whites are approximately twice as likely to earn a bachelor's degree than African Americans and Hispanics (Callan et al, 2006). The question becomes, how can postsecondary degree attainment be equitably increased for all students, particularly underprepared students who currently comprise the majority of students dropping out or stopping out of higher education (Callan et al, 2006).

Postsecondary Response to Underprepared Students

Developmental Education. (DE) programs have been available for almost 100 years at almost all public two-year and four-year postsecondary institutions, including Ivy League institutions, in an attempt to increase postsecondary success rates of underprepared students in math and English (Richardson, 2005; Bailey & Cho, 2010). As of 1998, 78% of postsecondary institutions in America provided some form of remediation (Bahr, 2010; Bettinger & Long, 2004; Merisotis and Phipps 2000). By design, developmental education was intended to address the high failure rates in credit-bearing courses for postsecondary undergraduates identified as "not college ready" or insufficiently prepared for the rigor of college level coursework (Bahr, 2008a; Bettinger & Long, 2009; Ganga, Mazzariello, Edgecombe, 2018). Because of the high failure rates reported for students taking postsecondary credit-bearing general education (GE) math courses, including college algebra, underprepared students entering public postsecondary institutions are often referred into DE math courses (Bahr, 2010). Students with prerequisite math and English/reading skill-deficiencies are placed in DE courses with the intention of improving their ability to succeed in college credit-bearing courses (Bahr, 2010; Bettinger and Long, 2004; Bailey, Jeong, & Cho, 2010;).

Although DE has been offered at public and private postsecondary institutions since the mid-19th century, no uniform national standard exists for DE course curriculum (Merisotis and Phipps 2000). The terminology "developmental education," also known as "remedial education," refers to courses that attempt to remediate or resolve skill deficiencies (Phipps, 1998; Kozeracki, 2002). Moreover, students enrolled in a DE course are often charged the same tuition per credit hour as that of a credit-bearing course, even though these courses receive institutional but not college-level credit, hence do not provide postsecondary credits toward degree attainment, (Adelman, 2004; Phipps, 1998; Kozeracki, 2002). Successful postsecondary remediation is defined as achieving a passing grade of an A, B, C or P in DE courses and successful completion of the subsequent college credit-bearing course (Bahr, 2007). Students referred to as non-DE students are considered college ready and are judged to have achieved the level of secondary preparation needed for direct enrollment in college credit-bearing courses (Chen, 2016; Conley, 2008).

Developmental Education Course Enrollment. Results from the NELS:88 survey found that the number of students enrolled in DE courses is substantially higher at public two-year institutions than public four-year institutions, with 60% of first-time college freshmen enrolling at public two-year institutions placed in at least one DE course compared to 30% at nonselective four-year institutions (Atwell et al, 2006). More recent results from the National Center for Educational Statistics (NCES) 2004/09 Beginning Postsecondary Students Longitudinal Study found that 68% of first-time freshmen at public two-year institutions were enrolled in DE coursework compared to 40% at public four-year institutions with math remediation more common than English/reading remediation (Adelman, 2004; An, 2013; Chen, 2016, Ganga, Mazzariello, Edgecombe, 2018). In 2011 through 2012, the number of first-time undergraduates enrolled in at least one DE course was 35% at four-year institutions, and 51% at two-year institutions (Schak, Metzger, Bass, McCann, English, 2017). The findings from these studies demonstrate that a substantial segment of secondary students continue to graduate underprepared to successfully complete college-level credit-bearing courses. One such credit-bearing course is college algebra, which is a gateway course for most STEM and MT competency-based professions (Thiel, Peterman, & Brown, 2008).

According to a recent study by the U.S. Department of Education, first-year, full-time bachelor's degree-seeking students who are placed in at least one DE course during their freshman year of postsecondary education are 74% more likely to drop out of college than their non-DE counterparts placed in only credit-bearing courses (Schak et al., 2017). Illich, Hagen & McCallister (2004) found students who passed all their DE courses while concurrently enrolled in college credit-bearing courses also passed 76.9% of their college level courses, which was similar to the 76.4% pass rate for students enrolled exclusively in college-level courses. Results from recent research involving multiple institutions found that students who successfully complete their required DE coursework have academic outcomes similar to non-DE students, while partial and non-completers recorded poor academic outcomes (Attewell, Lavin, Domina, & Levey, 2006; Bettinger & Long, 2004; Chen 2016). However, students who failed to pass one or more of their DE courses while concurrently enrolled in credit-bearing courses, passed their college-level courses at a much lower rate of 41.8% (Illich, Hagen & McCallister, 2004).

For many students, successful completion of one or more DE math courses is the first hurdle toward attaining a degree. Degree-seeking students enroll in DE math courses at a significantly higher rate than in DE English courses and fail their DE math courses at a proportionally higher rate, with a majority either not enrolling or failing on the first attempt (Attewell et al, 2006; Chen, 2016; Jaggers & Stacey, 2014; Levin & Calcagno, 2008). One study found the number of first-time postsecondary undergraduates referred to DE math was six times that of students referred to DE English (Jaggers & Stacey, 2014). According to a study by the

U.S. Department of Education, the three postsecondary courses that consistently have the highest non-passing (DFW) rate are all part of the developmental math course sequence (Adelman, 2004).

Degree Attainment for Developmental Education Students. Differences in degree attainment between students who successfully passed their DE math coursework (DE completers) and students who were not required to enroll in any DE math courses were found to be insignificant (Attewell et al, 2006). However, only 30% of DE students actually completed all of their DE math coursework compared to 71% who completed all of their DE English coursework. Adelman considered math remediation of underprepared students to be successful only if they passed their DE course(s) and continued on to earn college credit in an entry- level gateway math course such as college algebra, finite math, statistics, precalculus, calculus, or any college credit-bearing course that required the equivalent of high school Algebra 2 as a prerequisite (Adelman, 2006).

Complete College America (2013) followed a cohort of first-time, degree-seeking students from all levels of academic preparation who began their postsecondary education in the fall of 2007 (Shapiro, Dundar, Ziskin, Yuan & Harrell, 2013). They found that, after six years, 63% of students who started at four-year public institutions had completed a degree, compared to 40% of students who started at public two-year institutions. A 2016 study by the U.S. Department of Education followed the postsecondary progress of first-time freshman beginning their postsecondary education in 2003 (Chen 2016). The study tracked the cohort for six years and found 63% and 50% of DE students at two-year institutions completed all their DE courses, compared to four-year institutions, where 64% and 58% respectively, were English and math completers. Table 1, compiled from 2016 U.S. Department of Education results, displays the percent of DE and non-DE students at two- and four-year institutions earning college-level credit in English and math and subsequent degree attainment after six years. At two-year institutions, 71% of DE math completers went on to enroll in GE math courses and 62% successfully earned college-level math credit. This equates to only 31 out of 100 DE completers actually earning GE math credit.

Table 1

Percent of earned college-level credit & degree attainment for DE and non-DE students

Developmental Level	two-year institutions %	four-year institutions %
Enrolled in DE English	28	11
Enrolled in DE math	59	33
DE Completers	49	59
DE Partial Completers	35	25
DE Non-completers	16	15
English Non-DE college credit attainment	55	86
DE Completers college credit attainment	50	58
Math Non-DE college credit attainment	25	76
DE Completers college credit attainment	31	44
DE Partial Completers college credit attainment	10	13
DE Non-Completers college credit attainment	4	10
Non-DE associate degree attainment	24	15
DE Completers associate degree attainment	26	7
DE combined associate degree attainment	22	8
Non-DE bachelor’s degree attainment	4	67
DE Completers bachelor’s degree attainment	17	55
DE combined bachelor’s degree attainment	10.4	45

Created from the results of 2016 U.S. Department of Education report (Chen 2016).

Non-DE students fared even worse, with only 53% enrolling in GE math courses and 48% earning college-level credits at an overall rate of 25%. In contrast, 63 out of 100 DE English completers enrolled (85%) and successfully attained GE credit (77%) at an overall rate of 49%, almost 20 points higher than DE math completers (Chen, 2016). These results, combined with the differences in DE math and English enrollment, suggest that the inability of students to successfully pass a GE math course plays a critical role in student attrition and low degree attainment at two-year institutions. Non-DE students at both two- and four-year institutions earned more GE English credits than math credits. Earned credits and degree attainment was noticeably lower for DE students than non-DE students at four-year institutions compared to two-year institutions, in which DE completers outperformed their non-DE counterparts in both earning GE math credit and degree attainment. Although DE completers at two-year institutions performed the same or better than their non-DE counterparts, DE math partial completers and non-completers were significantly less likely to earn college-level credit and persist toward a 2 or four-year degree (Bahr, 2008a; Chen, 2016; Fong, Melguizo, & Prather, 2015).

Similar results were found by Jaggars and Stacey (2014) after analyzing the postsecondary outcomes of 57 community colleges with 11,210 DE English students and 63,650 DE math students enrolled in a three-tier developmental course sequence. They found that after eight years, of the approximately 75,000 students enrolled in a three-course developmental sequence, only 7,000 students earned GE math credit, and 3,250 students earned GE English credit, which means more than 64,000 underprepared students had not earned any college-level credit after eight years.

The results of these studies and others clearly demonstrate that, apart from DE completers at four-year institutions, fewer than 55 out of 100 underprepared postsecondary students persist to graduate with a degree or credential (Attewell et al, 2014; Chen, 2016; Jaggars, Stacey, 2014). Furthermore, it appears that failure to pass a GE math course seems to have a significant impact on persistence, degree attainment and attrition which negatively impacts employability prospects (Calcagno, Crosta, Bailey, Jenkins, 2007). Based on these outcomes, it is difficult to consider postsecondary remediation of underprepared students as successful.

Demographic Differences in Developmental Education Enrollment and successful remediation at the postsecondary level have been observed between different groups with significant economic and racial differences (Adelman, 2004; Bahr, 2010; Chen, 2016; Schak et al., 2017). Students from urban high schools were more likely to enroll in a developmental course when compared to students from suburban and rural high schools (Attewell et al., 2006). Overall 40% percent of African American students and 31% of Hispanic students enter college at the lowest level of math skill, compared to 17% of White students (Bahr, 2010). At two-year institutions, differences in DE course-taking rates were significant, at 78% of African American, 75% of Hispanic and, 64% of White students enrolled in DE courses (Ganga, Mazzariello, Edgecombe, 2018). Low-income students were enrolled in DE coursework at a rate of 76%, compared to 59% for their more affluent peers in the highest income group (Chen, 2016; Schak et al., 2017). Even greater demographic enrollment differences were found at public four-year institutions, with 66% of African American students, 53% of Hispanic students and 36% of White students enrolled in DE coursework. Likewise, 52% of low-income students enrolled in DE courses, compared to 33% of those from the highest income group (Chen, 2016; Schak et al., 2017).

White students are more likely to successfully complete their DE coursework and attain a degree than their African American and Hispanic peers. At two-year institutions, 25 out of 64 White students who enrolled in DE courses went on to graduate (40%) compared to 19 out of 78 African American students (24%) and 19 out of 75 Hispanic students (25%) (Ganga, Mazzariello, Edgecombe, 2018). The primary reason for such significant differences in success can be linked to initial differences in math skill after postsecondary matriculation and the first recorded, postsecondary math grade (Adelman, 2004; Bahr, 2010; Chen 2016). Successful remediation for students who have the weakest math skills is unacceptably low and it appears It appears that DE math education programs designed to address inequities in secondary preparation may unintentionally exacerbate racial differences in math achievement. (Bahr, 2010; Chen, 2016; Adelman 2006).

For African American students in the 1980-1993 High School & Beyond/Sophomore cohort longitudinal study (HS&B/So), 52.3% of those who reached 12th grade and enrolled in postsecondary education started in four-year colleges, a percentage that rose to 54.2% in the NELS:88/2000 cohort. Enrollment patterns for Hispanic students, who are more likely to start at community colleges, showed little change, at 38.9% for the 80/93 cohort and 38.6% for the 88/2000 cohort. For White students, the proportions starting in four-year institutions were 54.3% and 57.4%, respectively (Adelman, 2006). Success or failure in DE courses strongly correlates with success or failure in college-level courses, degree attainment and ultimately employability (Attewell, et al, 2014). Those who are the most vulnerable and in need of the most support are often served least by developmental education (Bahr, 2010).

Opponents of developmental education cite low completion rates, the high cost of reteaching of high school content, and the perception that institutions offering DE coursework are in some sense "dumbing down" the curriculum (Bahr, 2010; Bettinger, Boatman & Long, 2013; Levin & Calcagno, 2008). Proponents of developmental education consider DE coursework an opportunity to increase access to postsecondary education and address discrepancies in secondary preparation correlated with race, gender and SES (Attewell, et al, 2014). They site research linking the lack of postsecondary degree attainment to insufficient secondary preparation rather than developmental education enrollment (Adelman, 1999, 2004; Bahr, 2008a) The monetary cost of DE is also considered necessary to mediate the misalignment between the academic expectations of secondary and postsecondary expectations and justified by the potential social cost of failure to allow underprepared students access to postsecondary education (Bettinger, Boatman & Long, 2013; Parker, 2007).

Alternatives to Developmental Education are being implemented in response to low DE success rates and in an attempt to expedite degree attainment. Accelerated/co-requisite courses, developed for underprepared students, include enhanced academic supports, such as additional hours of instruction, tutoring, mentoring, or advising (Hu, Jones, Park, Tandberg & Woods, 2018). Instead of taking DE courses, students identified as moderately underprepared enroll in a credit-bearing math course and attend additional corequisite/accelerated labs/seminars as part of the course, which allows them to move through their required coursework with targeted support and without adding additional semesters and the expense of taking non-credit bearing classes. (Adelman, 2004; Bahr, 2010; Chen 2016). The success of corequisite/accelerated courses is promising. Research by Hu et al (2018) found underprepared students who enrolled in corequisite/accelerated courses passed at a rate of approximately 50% compared with 40.8% who took credit-bearing courses with no DE courses or supports. Other research has shown noticeable improvement in college-level credit attainment for students enrolled in corequisite/accelerated math courses compared to those enrolled in the traditional developmental prerequisite model (Bettinger, Boatman & Long, 2013; Kashyap & Mathew, 2017; Ganga, Mazzariello, Edgecombe, 2018)

In 2014, The Kentucky Council on Postsecondary Education (CPE) began encouraging two- and four-year institutions to offer corequisite/accelerated math and English courses in place of DE courses and, as of fall 2019, four-year institutions were allowed to offer only credit bearing corequisite/accelerated courses to underprepared students needing remediation in core content areas (http://cpe.ky.gov). Kentucky and several other states are eliminating remediation in four-year institutions and shifting the responsibility of developmental education to community colleges (Parker, 2007). On the surface this seems counterintuitive based on the results of multiple studies that show underprepared students are less likely to graduate with a degree from a two-year community college than are students who initially enroll in a four-year institution (Bettinger & Long, 2004; Chen, 2016; Levin & Calcagno, 2008).

In summary, although accelerated/corequisite courses are reporting better outcomes than developmental education, remediating underprepared students at the postsecondary level is not an effective strategy for addressing insufficient high school preparation. Postsecondary and secondary must work together to address the problem of underprepared students and low postsecondary degree attainment, or the misalignment will continue to hinder postsecondary degree attainment (Bailey & Karp, 2003; Kirst and Usdan, 2009).

College Algebra

> "*The study of mathematics stands, in many ways, as a gateway to student success in education. This is becoming particularly true as our*

society moves inexorably into the technological age. Therefore, it is vital that more students develop higher levels of competency in mathematics"

(Parnell, 1988, p. 1 – in Wynegar and Fenster, 2009).

There has been a steady decline in U.S. STEM degree gradates, with fewer than half of the postsecondary students who declare a major in science or engineering actually attaining a degree in these career fields (Thiel, Peterman & Brown, 2008). Students from developing countries are more likely to earn a STEM degree, than U.S. students (Thiel, Peterman & Brown, 2008). Entry-level qualifications for many lucrative careers which require a postsecondary degree or credential, necessitate successful completion of a credit-bearing postsecondary math course (Sithole, Chiyaka, McCarthy, Mupinga, Bucklein, & Kibirige, 2017; ACT, 2018). Two- and four-year degree attainment has been shown to correlate with the successful completion of college-level math coursework, and earning the required number of math credits necessary for degree completion requires a sufficient level of mathematical preparation and proficiency (Adelman,1999; Bahr, 2010; Niu & Tienda 2013).

College algebra is a core course required for graduation at approximately 98% of community colleges and considered a gateway course to further postsecondary education (Herriott & Dunbar, 2009; Li, Uvah, Amin & Hemasinha, 2009; Wynegar & Fenster. 2009). One of the primary roles of college algebra is to prepare students for calculus; however, for students who are not initially placed in higher level math courses, college algebra is also a required gateway course for business, STEM, health, or other math or technology (MT) competency-based fields (Barnes, Cerrito & Levi 2004; Herriott & Dunbar, 2009; Thiel, Peterman, & Brown, 2008). Although much of the curriculum repeats content covered in a typical high school Algebra 2 course, college algebra is considered a high-risk course and presents an academic barrier for many students, particularly underserved populations, with one of the highest first-time failure rate of any entry level GE mathematics course (Cortés Suárez & Sandiford 2008; Herriott & Dunbar, 2009; Leong & Alexander, 2014; Li, Uvah, Amin & Hemasinha, 2009; Porter, Ofoldile & Carthon, 2015; Thiel, Peterman, & Brown, 2008). Referred to as "the single most failed course in community colleges," college algebra has become the gatekeeper for many students seeking a postsecondary degree (Ganga & Mazzariello, 2018, p. 2; Herriot, 2006; Li, Uvah, Amin & Okafor, 2010; Porter, Ofoldile, & Carthon, 2015; Wynegar, & Fenster, 2009).

A passing grade in college algebra is defined as receiving an A, B or C, and DFW rates for college algebra and pre-calculus exceed 50% at many postsecondary institutions (Barnes, Cerrito & Levi 2004; Li, Uvah, Amin & Hemasinha, 2009; Thiel, Peterman & Brown, 2008; Sithole et al, 2017). Because so many degree programs require college algebra as a GE gateway course, it is critical that students can successfully pass with an A, B or C; however, national passing rates for a traditional lecture-based college algebra course fall between 40 and 60 percent, with a majority of postsecondary institution reporting passing rates below 50% (Burd & Boser, 2009; Ganga & Mazzariello, 2018; Hopf, 2011; Herriott & Dunbar, 2009; Leong & Alexander, 2014; Li, Uvah, Amin & Hemasinha, 2009; Thiel, Peterman & Brown, 2008). Failure to successfully pass college algebra can limit a student's field of study and ultimately become a barrier to degree attainment, particularly for those from underserved populations (Thiel, Peterman, & Brown, 2008). In contrast, those who successfully complete college algebra as a dual credit course are significantly more likely to progress toward a degree of their choice (Speroni, 2011).

Low pass rates, combined with limits on long term financial aid, can increase time and cost before graduation and negatively impact successful postsecondary degree attainment.

However, before students can pass college algebra, they must first enroll. Jenkins, Jaggars & Roksa (2009) found enrollment in college algebra was not only low for students who started in the lowest level of developmental math (19%) but also for students who, based on their test scores and recommendations, were well prepared for college-level work (39%). In fact, two thirds of first-time, full-time freshmen never enrolled in a gatekeeper math course, compared to approximately one third of students who did not enroll in a gatekeeper English, writing and reading course. Of those who did enroll in their required GE math course, 73% successfully passed (Jenkins, Jaggars & Roksa, 2009).

Unfortunately, high school students are often unaware of postsecondary academic and social expectations and struggle to succeed once they arrive on campus (Conley, 2005). Lack of alignment between secondary and postsecondary institutions leaves first-time freshmen without the core academic knowledge, skills and insight into postsecondary expectations necessary for success (Cohen, 2008; Conley, 2005). Barnes, Cerrito & Levi (2004) surveyed a cohort of undergraduate students enrolled in GE mathematics and DE intermediate algebra courses and reported that 35% of the students were enrolled in contemporary math, finite math, elementary statistics, trigonometry, math for elementary education, precalculus and intro to calculus, 24% were enrolled in college algebra and 41% were enrolled in DE intermediate algebra. A clear disconnect between faculty and student expectations was demonstrated by survey responses to questions about faculty and course expectations when 35% of the respondents reported they expected to spend one hour or less per week studying outside of class, 96% expected to study less than faculty indicated in their syllabus, 40% believed too much was demanded of them in their math course, and 44% of those enrolled in intermediate algebra or college algebra indicated surprise at the amount of foundational material not covered during class that faculty expected them to have retained from high school or a previous course. A follow-up study tracking students who passed college algebra with a C or higher and enrolled in precalculus found that approximately 50% or more of the students who received an A, B or C in college algebra withdrew or failed to earn a passing grade (A, B or C) in precalculus.

College Algebra Course Redesign

In response to low pass rates and studies linking non-cognitive factors to student success, some institutions have begun making comprehensive changes to their college algebra course structure to incorporate non-cognitive factors identified as part of student learning. These institutions have experienced substantial increases in college algebra enrollment and passing rates (Hagerty, Smith & Goodwin, 2010; Porter, Ofoldile & Carthon, 2015; Thiel, Peterman & Brown, 2008). Although college algebra course redesign differs by institution, they include many elements of the "Key Quality Improvement Strategies" recommendations made by the 2005 National Center for Public Policy and Higher Education Policy Alert. The improvement strategies are online tutorials, continuous assessment and feedback, increased interactions among students, on-demand support, and mastery learning (Twigg, 2005).

A critical component of successful redesign includes detailed course plans, faculty training, and professional development (Hagerty, Smith & Goodwin, 2010; Porter, Ofoldile & Carthon, 2015; Thiel, Peterman & Brown, 2008). The University of Missouri-St. Louis and African American Hills State University (BHSU) detail their redesign of college algebra using continuous assessment and feedback through software-based homework, which provided online tutorials, immediate assessment and feedback, mastery learning, and allowed students to work on homework anytime and anywhere as long as they had an internet connection (Hagerty, Smith & Goodwin, 2010; Thiel, Peterman & Brown, 2008). The traditional lecture-based teaching pedagogy was abandoned in favor of one or two lectures a week, allowing instructors and assistants to focus on small group, targeted teaching, individual instruction and one-on-one interactions with students. Teaching time shifted from lecture to student-directed learning with peer-to-peer teaching and tutoring, student presentations, historical connections, whole class discussions, cooperative learning, writing and communication development, and relevant applications problems (Hagerty, Smith & Goodwin, 2010; Porter, Ofoldile & Carthon, 2015; Thiel, Peterman & Brown, 2008). Students were able to spend more time doing math and less time passively listening to lectures (Thiel, Peterman & Brown, 2008).

The results of the college algebra redesign at the University of Missouri-St. Louis were notable. Over a period of three years, student success increased from about 55 % to more than 75%, with fewer student repeating the course. Rigor and performance were maintained as measured by student scores on a final exam, which included the same types of problems found in the traditional college algebra course (Thiel, Peterman & Brown, 2008).

The BHSU college algebra redesign, was implemented to increase both enrollment in upper level math courses and student interest in mathematics fields of study (Hagerty, Smith & Goodwin, 2010). The development of the BHSU college algebra redesign incorporated discussions with faculty in the departments of sociology, psychology, and education along with evaluations and discussions of the National Council of Teachers of Mathematics (NCTM) Standards, the Mathematical Association of America's Committee on the Undergraduate Program in Mathematics (CUPM) Curriculum Guide, and the educational theories of Silver, Vygotsky, Bandura, and Bloom. After three years, the redesigned course resulted in a 21% increase in passing rates, from 54% to 75%, and a 300% increase in precalculus and trigonometry passing rates. A 25% increase in attendance was also noted, accompanied by a statistically significant increase in Collegiate Assessment of Academic Proficiency (CAAP) test scores. The redesign also encouraged student development in analytical thought, creative reasoning, problem solving, and communication skills.

The college algebra course redesign pilot at Albany State University, an HBCU (Historically African American Colleges and Universities), included components of cooperative learning, student presentations, writing assignments, bonuses, and quizzes (Porter, Ofoldile & Carthon, 2015). The varied assessment practices included multiple choice and short answer tests, problem solving, presentations, writing assignments, and homework assignments (Porter, Ofoldile & Carthon, 2015, p. 2). Average department pass rates increased from 51.9% to 72.7% after a one-year implementation, and average scores on departmental standardized final exams improved from 58% to 70%. One mathematics faculty member experienced an historical 14.4% increase in student passing rates compared to previous semesters.

These studies demonstrate that changes in methodology and pedagogy that emphasize active learning and whole student development and growth, not just content assimilation, can lead to increased success in college algebra. High expectations, confidence, attribution, productive struggle, active learning, and collaboration are just a few of the noncognitive factors necessary for postsecondary success and need to be part of secondary math preparation (Hagerty, Smith & Goodwin, 2010; Porter, Ofoldile & Carthon, 2015; Thiel, Peterman & Brown, 2008).

The Access to Algebra (A2A) dual credit college algebra program contains many of the same features as the redesigned programs, with some modifications to operate in a dual credit setting. Ongoing professional development and collaboration between postsecondary and secondary faculty, organically formed learning communities, high rigor and expectations, software-based homework, online tutorials, continuous assessment and feedback, mastery learning, one or two lectures a week, individual instruction, one-on-one interactions with students, peer to peer teaching and tutoring, student presentations, whole class discussions, and cooperative learning are all part of the methodology and pedagogy supporting the A2A dual credit college algebra course. High school students who are exposed to postsecondary expectations in a supportive high school environment tend to have higher levels of motivation and engagement than their non-accelerated peers (An, 2015). In turn, secondary faculty are directly exposed to the postsecondary content and expectations necessary for their students to achieve postsecondary success (Cho, Karp, 2013).

College Readiness and Standardized Testing

Currently in the U.S., one of the most commonly used and most influential indicators of "college readiness" are standardized test scores such as the ACT and SAT, which are widely used by postsecondary institutions for college admissions (Fields & Parsad, 2012; Schak et al., 2017). Admission offices at postsecondary institutions use ACT/SAT scores to supplement secondary school records in order to put local assessments, such as coursework, grades, and class rank, in a national context (Qiu & Wu, 2010). Some states use the ACT score to assess secondary school performance and require all high school students to take the test regardless of whether they are college bound (ACT, 2007; Qiu & Wu, 2010).

Most postsecondary institutions rely heavily on standardized test scores not only for admission criteria, but as the primary method for classifying students as college ready in reading, writing, and math (ACT, 2017; Fields & Parsad, 2012; Schak et al., 2017). Standardized test scores are often used to determine student placement into developmental education for math, reading and writing based on a single cut score, although some post-secondary institutions use a combination of ACT/SAT subscores, high school GPA, and other measures in their evaluation of college readiness (Fields & Parsad, 2012; Noble & Sawyer, 2004; Schak et al., 2017; Westrick, Le, Robbins, Radunzel & Schmidt, 2015). In a national survey, the overall mean ACT/SAT cut scores used for placement in non-college algebra entry-level GE math courses was found to be 19 on the ACT and 471 on the SAT (Fields & Parsad, 2012). The national mean cut score used by different institutions for college algebra placement as reported by the National Assessment Governing Board (NAGB) was a math subscore of 21 on the ACT and a math subscore of 490 on the SAT (Fields & Parsad, 2012; Li, Uvah, Amin & Okafor, 2010)

The question of ACT/SAT validity in predicting college readiness and first-year, postsecondary success has been investigated by several researchers. Studies analyzing the difference in predicting first-year college academic success based on the ACT composite score found that ACT was a better predictor of first-year college GPA for students with a high school GPA between 3.0 and 4.0 (Noble & Sawyer, 2004). However, for college GPAs of 3.0 and lower, high school GPA was a better predictor than ACT scores. (Noble & Sawyer, 2004; Westrick, Le, Robbins, Radunzel & Schmidt, 2015). ACT composite scores combined with high school GPA was consistently the best predictor of first-year academic success, and first-year college GPA was found to be the best predictor of second- and third-year persistence (Noble & Sawyer, 2004; Westrick, Le, Robbins, Radunzel & Schmidt, 2015

Geiser & Santelices (2007) examined the correlation between SAT test scores, high school GPA and long-term postsecondary outcomes for undergraduates at University of California campuses. They found that high school GPA alone was again consistently the strongest predictor of college GPA as well as four-year graduation rates, They also found the predictive power of high school GPA increased in strength with each year of postsecondary persistence and the predictive value of high school GPA combined with the SAT II test scores had the highest correlation. The results of these studies contradict assumptions held by many in postsecondary that high school GPA is an unreliable measure of student preparation. Perhaps high school GPA measures a depth of persistence that cannot be captured by a standardized test.

College Readiness and Non-cognitive Factors

Even though the predictive strength of high school GPA combined with ACT/SAT has been well documented, it explains less than half of the total variance in postsecondary outcomes (ACT, 2007; Geiser & Santelices, 2007; Huy, Robbins, Radunzel, Schmidt, Westrick, 2015; Noble, Roberts & Sawyer, 2006). Clearly, factors other than academic performance play an important role in predicting postsecondary success. Accepting standardized test scores as the primary criterion for student placement in college-level or developmental course work fails to consider student motivation, attitude, persistence, and other non-cognitive factors that impact postsecondary outcomes but cannot be measured by a standardized test score.

In a study by Jenkins, Jaggars & Roksa (2009), comparisons between non-DE math students, DE math completers and those who did not comply with their DE recommendation (DE skippers), revealed minimal differences in GE math passing rates of 78%, 72% and 68%, respectively. The difference in passing rates, at 4%, between DE skippers and DE completers was relatively small. However, enrollment in GE math course was substantially different between non-DE math students (75%), DE math completers (31%), and skippers (35%). (Jenkins, Jaggars & Roksa, 2009). Similar results were reported by Park, Woods, Hu, Bertrand Jones & Tandberg (2018) in Florida after developmental education was made optional. Even though relative passing rates for gateway math courses declined as enrollment increased, there was an overall net increase in the number of students earning GE math credits. These studies demonstrate that, when given the opportunity, underprepared students can successfully attain college-level credit without remediation, since standardized test scores cannot measure a variety of nonacademic factors such as strong oral and written communication skills, the ability to problem solve, analytical thinking, persistence, and independent learning proficiency (ACT, 2007; Akey, 2006; An, 2013; Dweck, Legget, 1988; Geiser & Santelices, 2007; Huy, Robbins, Radunzel, Schmidt, Westrick, 2015; Kwon & Rasmussen, 2007; Noble, Roberts & Sawyer, 2006).

Secondary Preparation and Postsecondary Success

Although easy to assess, standardized test scores and placement exams are insufficient measures of secondary student preparation for postsecondary education. College readiness, defined as the level of proficiency needed to equip students for postsecondary coursework and degree attainment without remediation, must involve more than test scores and high school GPA (Bettinger, Boatman & Long, 2013; Li, Uvah, Amin & Okafor, 2010; Venezia & Jaeger, 2013). Too many secondary students fail to meet college readiness math benchmarks an those that do often fail to successfully pass college algebra, which is a first-year GE math course (Chen, 2016; Thiel, Peterman, & Brown, 2008).

Measuring College Readiness. According to the 2019 National Assessment of Educational Progress 66% of high school graduates enroll in a postsecondary institution are ill-prepared for college-level coursework, with barely a fourth of high school seniors scoring proficiently in mathematics, and a majority scoring at basic or below basic (McFarland, Hussar, Zhang, Wang, Wang, Hein, Diliberti, Forrest Cataldi, Bullock Mann & Barmer, 2019). Meeting college and career benchmarks indicates a 65% likelihood of obtaining a B average or higher during the first year of college; however, data from the ACT (2005) shows the probability of meeting the college readiness benchmarks for math after taking Algebra 1, geometry, algebra 2, and precalculus was only 37% (Venezia & Jaeger, 2013). According to the ACT, college readiness decreased from 2014 to 2017, with 35% of 2018 graduates meeting none of the ACT College Readiness Benchmarks, compared to 31% in 2014 and 33% in 2017 (ACT 2018).

Studies consistently find that math and science have the lowest benchmark passing rates, which are substantially lower than reading and writing (ACT, 2007, 2015, 2018; Boser & Burd, 2009). Low-income, minority, and first-generation students make up 43% of all ACT-tested high school graduates, and fewer than 25% of these students demonstrate readiness for college coursework, which means that more than a half-million recent high school graduates and their families spent on average $3,000 to $4,000 on college tuition to study content and skills they should have learned in high school (Barry & Dannenberg, 2016). Based on standardized test benchmarks and postsecondary GE math passing rates, it is clear that a substantial misalignment exists between secondary preparation and postsecondary expectations.

Preparation Gaps Between Secondary and Postsecondary. The lack of institutional alignment between secondary and postsecondary institutions has deep historical roots. During the last century, as high school enrollment increased dramatically, many high school graduates went on to work as part of the middle-class economy without a postsecondary credential or degree since a high school degree was sufficient for middle class employment (Hoffman, Vargas, Venezia., & Miller, 2007). However, as reported by Hoffman et al (2007), employment opportunities have shifted to the point that a postsecondary degree or credential has replaced a high school degree as the necessary requirement for middle-class employability, hence the primary purpose of secondary education has shifted from career preparation to postsecondary degree preparation (Carnevale, Smith, & Strohl, 2010). Because the K-12 and postsecondary systems are poorly aligned and largely function independently with divergent institutional boundaries, governance, and policy structure, far too many high school graduates enroll in postsecondary institutions unaware they are insufficiently prepared to handle college-level coursework (Callan, Finney, Kirst, Usdan & Venezia, 2006; Chen, 2016).

Over the last century, the gap between K-12 and postsecondary has expanded as the number of school-age students participating in K-12 public education increased (Bailey & Karp, 2003; Kirst & Usdan, 2009; Stanic & Kilpatrick, 1992). Kirst and Usdan (2009) document the National Education Association's (NEA) 1892 attempt to unify secondary and postsecondary curriculum and expectations by appointing of the Committee of Ten. This committee was primarily composed of postsecondary educators tasked with creating curriculum and standards for U.S. public schools that would link secondary preparation to postsecondary expectations. The committee recommended eight years of elementary education followed by four years of high school (Kirst & Usdan, 2009; Stanic & Kilpatrick, 1992). According to Kirst and Usdan (2009), at the beginning of the 19th century, only a small portion of high school graduates continued their education, and postsecondary institutions were able to individually accredit regional high schools that had the curricula and preparation needed for successful matriculation. However, as the number of high schools and postsecondary institutions grew, the logistics of joint accreditation became more challenging and the K-12 accreditation system eventually separated from postsecondary institutional accreditation, which ultimately became an obstacle to secondary/postsecondary alignment (Bailey & Karp, 2003; Kirst & Usdan, 2009).

The historical gap between secondary and postsecondary institutions must be bridged through collaboration and mutual accountability (Kirst, Usdan, 2009; Vargas & Venezia, 2015). More robust measures for ascertaining college readiness at the secondary level need to be developed based on input from postsecondary institutions including recommendations on academic standards, assessments, and expectations which must become an integral part of the secondary curriculum to ensure that graduating high school students are well prepared for postsecondary degree attainment (Cohen, 2008; Vargas & Venezia, 2015). Graduating high school seniors who are well prepared are more likely to experience first-year, postsecondary academic success and persist through each following year, ultimately attaining a degree (Geiser & Santelices, 2007; Li, Uvah, Amin & Okafor, 2010; Noble & Sawyer, 2004; Westrick, Le, Robbins, Radunzel & Schmidt, 2015). What type of academic standards, assessments, and expectations are needed to ensure that all graduating high school students are truly ready for first-year postsecondary education? Of equal importance, how can secondary institutions better prepare students for success in GE gateway math courses, specifically college algebra? Several ideas have been suggested for closing the gap between secondary and postsecondary institutions including a shared accountability system, aligning curriculum, standards, assessments and high school graduation requirements, increasing the pacing, rigor, workload, depth of knowledge, active learning and engagement of the high school curriculum (Adelman, 2006; American diploma project, 2004; Bangser, 2008; Long, Iatarola & Conger, 2009; Conley, 2003)

The Impact of Secondary Course Intensity and Postsecondary Success. Multiple studies report that the academic intensity of the high school curriculum is the most important pre-collegiate factor influencing bachelor's degree completion with Algebra II and other advanced courses identified as prerequisites for many college courses, not only in math and science, but also in social science fields, economics, business, and computer and other technology courses (Achieve, 2008; Adelman, 1999, 2006; Attewell, Lavin, Domina, & Levey, 2006; Park et al, 2018). In 1999, leading governors and business leaders attending the National Education Summit founded Achieve, Inc., with the mission of identifying the “must-have” knowledge and skills required by postsecondary and employers. Algebra II was identified as a gateway course that would improve access to postsecondary education, reduce the need for remediation and significantly increase the odds that a student would earn a degree (Achieve, 2009). Part of the mission of Achieve, Inc. was to improve the rigor of the high school Algebra II curriculum and design a common curriculum to provide consistency across and within states. A uniform, high-quality, rigorous end of course Algebra II assessment was created to increase expectations, assess student achievement, and serve as an indicator of secondary preparation and postsecondary math readiness (Achieve, 2009).

Adelman (2006) found low SES, gender and minority status reduce the probability of earning a bachelor's degree because students in these groups often lack access to secondary academic resources, a quality learning environment, and rigorous academic curriculum, which in turn negatively affects postsecondary outcomes. Although improvement in any of these areas would positively influence postsecondary outcomes, Adelman found increasing the intensity of the high school curriculum had the highest impact on postsecondary success and degree completion. Math curriculum intensity exhibited the strongest correlation with bachelor's degree attainment, followed by class rank/GPA and test scores. Students who take more academically intense math courses in high school have higher rates of enrollment and persistence in postsecondary education than similar students who pursue fewer challenging courses (Adelman, 2006; Nobles, 2007; Oakes & Saunders, 2007). However, Aldeman (2006) found that the Algebra 2 curriculum was not sufficient preparation for postsecondary degree attainment in several fields of study. Students who completed Algebra 2 and one other advanced course, such as precalculus or above, were found to have a significant positive association with persistence to degree compared to students who completed Algebra 2 or lower (Adelman, 2006; Niu & Tienda

2013). Underprepared students who took rigorous math courses, such as trigonometry and AP English, in high school were more likely to pass intermediate algebra, even after controlling for their relative Postsecondary Education Readiness Test (PERT) math score (Park, Woods, Hu, Bertrand Jones & Tandberg, 2018).

Secondary student intent to major in a STEM field has been correlated to 12th grade math achievement, exposure to math and sciences, parental support, SES, racial status, and math self-efficacy beliefs, which have been shown to increase academic persistence in the face of adversity and obstacles. (Adelman, 2006; Chen 2009; Tsui, 2007; Bandura, 198l; Sithole, Chiyaka, McCarthy, Mupinga, Bucklein, & Kibirige, 2017; Wang, 2013). Exposure to math and science courses was found to be a stronger predictor of STEM intent than that of math achievement, although math achievement still correlated significantly with STEM intent and subsequent declaration of a STEM degree (Wang, 2013). However, for underrepresented minorities, Wang (2013) found that 10th grade math achievement, which correlated with 12th grade math self-efficacy beliefs and achievement, had a much larger effect on STEM intent than exposure to math and science. Unfortunately, a majority of STEM majors either drop out, fail, or change their major to non-STEM programs, such as social sciences, humanities, or business (Sithole et al, 2017). Furthermore, gender and race/ethnicity seem to be significant factors since females and African Americans are two groups with the highest STEM dropout rates (Sithole et al, 2017; Wang, 2013). After controlling for prior academic preparation and other student characteristics, African Americans and female students were the least likely to enroll in gateway math coursework. Curriculum, preparation, and the racial gap in math achievement must be addressed early enough to forestall harmful cumulative effects on math self-efficacy and achievement (Tsui, 2007; Wang, 2013).

The Common Core Standards. The Common Core State Standards (CCSS) were developed with the intention of nationally aligning standards across K-12 to better prepare students for postsecondary success by intensifying the depth of content and conceptual knowledge acquired in K-12 math courses. The Common Core initiative was launched in 2009 by state leaders, including governors and state commissioners of education from 48 states, two territories, and the District of Columbia, in an effort to ensure all students, regardless of where they live, graduate from high school prepared for college, career, and life (Common Core Standards, Development Process, 2010). The development of the standards began with research-based learning progressions detailing what was known about how mathematical knowledge, skill, and understanding develop over time (Common Core Standards, Development Process, 2010).

The standards were divided into two categories: college and career-readiness standards, and K-12 standards. The progression of the CCSS were designed to be mathematically coherent and systematically increase a student's conceptual and procedural understanding, ultimately equipping them to be college-and career-ready at an internationally competitive level (Common Core Standards, Development Process, 2010). CCSS are intended to enable teachers to focus less on lecture and more on facilitating and increasing expectations and rigor while moving students away from rote memorization into active learning and deeper conceptual understanding of why and how. Woven throughout the mathematics standards are opportunities for students to learn how to construct arguments, critique others, effectively communicate, reason logically, think critically and interpret, analyze, and synthesis information (Venezia & Jaeger, 2013). Long, Iatarola & Conger (2009) found students' eighth-grade test scores had a stronger effect than any other characteristic on the highest level of math taken in high school, hence effective implementation of the Common Core Standards could positively impact postsecondary success long before high school graduation. Identifying academic and non-cognitive factors and addressing mathematical deficits that affect the success or failure rates of underprepared students as early as possible, long before secondary graduation, is critical in reducing the need for remediation and increasing postsecondary persistence and degree completion (Long, Iatarola & Conger, 2009). However, despite implementation of CCSS standards and increased requirements for high school graduation, barely one-third of graduating high school seniors are prepared for college-level mathematics, and the outlook is particularly poor for low-income families, Hispanics, and African Americans who are much more likely to be placed in developmental math coursework (Li, Uvah, Amin & Okafor, 2010).

Workforce Expectations. The American Diploma Project (2004) advocated developing a college- and work-ready curriculum to align secondary standards and graduation requirements including postsecondary and workplace expectations. This includes 21st century skill development focused on quantitative STEM knowledge and skills, technical content, transferable skills, habits of mind, and preparation for civic engagement (Venezia & Jaeger, 2013). High school must not only prepare graduates for postsecondary success but also for employment in an information-based economy (Bangser, 2008). Students who enter the workforce immediately after graduating from high school will need the same level of skill and knowledge as students who matriculate to a postsecondary institution (Bangser, 2008; Kline & Williams, 2007). Several surveys found that graduates failed to meet employer expectations in academic areas, good work habits and 21st century employability skills, such as teamwork and collaboration (Bangser, 2008).

Student Attitudes and Expectations. High school students are considered prepared for college-level math coursework based on their standardized test scores and high school GPA, although high school GPA and standardized test scores were shown to account for less than 50% of first-year postsecondary GPA (Conley, 2005; Geiser & Santelices, 2007). Survey results from one college algebra program revealed students with high-level test scores, recommended placements, and those with AP calculus credit doubted their own mathematical ability and potential for success in higher- level math courses (Hagerty, Smith & Goodwin, 2010). Other studies have found that positively oriented students are academically more successful and tend to attribute their success to effort, task difficulty, and causes over which they had control compared to their negatively oriented peers (Cortes-Suarez, 2004; Noble, Roberts & Sawyer, 2006). Moreover, student attitudes about math and confidence in their ability directly/indirectly impacts their success (Martino & Zan, 2009, 2010; Noble, Roberts & Sawyer, 2006). "Any good mathematics teacher would be quick to point out that students' success or failure in solving a problem is often as much a matter of self-confidence, motivation, perseverance, and many other non-cognitive traits, as the mathematical knowledge they possess (Lester, Garofalo, & Lambdin Kroll, 1989, p. 75).

Dweck & Leggett (1988) identified two different types of goal orientations – learning approach and performance goal orientation – that affect students' attitudes and performance in math. Students with a learning approach goal orientation focus on learning and mastering content, have higher self-efficacy, task engagement, academic achievement, and attribute success to effort, which leads to a positive math attitude, persistence and achievement when compared to students with a performance goal orientation, who tend to focus on outperforming their peers and often seek to avoid looking incompetent (Akin, 2012; Dweck & Leggett, 1988). Since math requires effort and persistence, students with performance goal orientation demonstrate negative math attitudes and are more likely to withdraw from learning activities that require productive struggle (Akin, 2012; Dweck & Leggett, 1988). Clearly, factors unrelated to ability or skill such as a self-concept, motivation, persistence, fear of math, or lack of interest in algebra can impact student enrollment in and successful completion of college algebra, which in turn affects student progress toward degree attainment (Akin, 2012; Jenkins, Jaggars & Roksa, 2009; Thiel, Peterman & Brown, 2008).

Aligning Attitudes and Expectations between secondary and postsecondary for first-year, credit-bearing coursework involves more than just content knowledge (Venezia & Jaeger, 2013). Many first-year students find the nature of college courses to be substantially different than high school courses (Li, Uvah, Amin & Okafor, 2010). High school students are often accustomed to passive learning instead of active learning, completing tasks that require little cognitive engagement, solving problems with simple solutions, and focusing on finding the "right" answer instead of drawing inferences, analyzing clues, interpreting results and being prepared to justify conclusions (Conley, 2007; National Research Council, 2002). Somehow the secondary curriculum must be aligned to encourage critical thinking, persistence, the ability to learn from mistakes, support arguments with evidence, solve complex problems, draw conclusions, offer explanations, conduct research, and think deeply about what they are learning (Conley, 2007; National Research Council, 2002). Conley (2012, p. 2) compiled 18 years of research on college and career readiness and identified four key domains that are essential to genuine college readiness.

1) Cognitive strategies – ways of thinking, such as formulating a hypothesis, problem-solving strategies, critical thinking, analysis, organization, and precision thinking.

2) Content knowledge – knowledge of the “big ideas” students must know well, retention of knowledge, and both technical knowledge and skills associated with their career aspirations.
3) Learning skills and techniques – independent learning such as ownership of learning, goal, setting, persistence, self-awareness, motivation, time management, study skills strategic reading, collaborative learning, and technology skills.
4) Transitionary knowledge and skills – the ability to successfully transition to life beyond high school, which includes knowing what courses to take in high school, understanding financial aid options, a focused career pathway, understanding postsecondary and workforce norms and expectations, and how to be a self-advocate.

Students should be able to collaborate comfortably with others and clearly communicate what they have learned (Adelman, 2006; Conley, 2007, National Research Council, 2002; Venezia & Jaeger, 2013). Furthermore, the math curriculum needs to hold students to higher standards and engage students in active problem solving, less rote memorization of algorithms, productive struggle and persistence along with deeper conceptual learning and exploration (Adelman, 2006; Conley, 2007).

Metacognition is not a part of the learning process for most secondary students. Rather, the goal is to complete an activity instead of understanding the deeper purpose of the assignment and information is memorized for exams and then discarded (Hagerty, Smith & Goodwin, 2010). Active learning is the key to knowledge retention and some form of productive struggle is needed in mathematics for students to make sense of the mathematical concepts not immediately apparent (Bandura, 1986; Hiebert & Grouws, 2007; Thiel, Peterman, & Brown, 2008). High school students accustomed to passive learning, with an emphasis on completing an activity versus understanding the information, will often object to “not being taught” when they find themselves struggling through the active learning process (Hagerty, Smith & Goodwin, 2010; Thiel, Peterman & Brown, 2008). Students learn by doing math, not by listening to someone else talk about math, and unless students recognize they can successfully learn through struggle, they will continue to perform poorly in postsecondary math courses and avoid mathematically challenging fields of study (Hagerty, Smith & Goodwin, 2010; Twigg, 2005). Teachers at all levels should learn how to provide students with opportunities to successfully persist through difficult course material. (Hagerty, Smith & Goodwin, 2010).

Voelkl (1995) examined the impact of warmth and student participation on achievement. Warmth was found to be significantly related to student participation and achievement, but when student participation was eliminated, the relationship between warmth and achievement disappeared. When teachers alter their instruction to include student activities, students’ perceived sense of learning is enhanced, and they feel more academically prepared (Salvaterra, Lare, Gnall & Adams, 1999).

Quality teaching tends toward depth over breadth, but for many secondary school districts, the focus of education is on attaining higher test scores and the accompanying monetary rewards instead of enhanced student learning. The result can be that teachers feel pressured to sacrifice depth for breadth of learning (Adelman, 2006; Salvaterra, Lare, Gnall & Adams, 1999). Teachers make a difference, and secondary faculty should be supported and trained in pedagogies and methodologies that engage student in active learning and promote postsecondary metacognitive practices (Salvaterra, Lare, Gnall & Adams, 1999). Schools that have not provided training and professional development for their teachers in active learning will most likely have negative results when implementing comprehensive and rigorous curriculum and pedagogical changes (Venizia & Jaeger, 2013).

Aligning Advising. Student advising during the transition from high school to college presents another critical gap in secondary and postsecondary alignment. The National High School Center has proposed creating a state level P-16 system for tracking students across the K–12 and postsecondary education systems and holding both secondary and postsecondary institutions accountable for student success (Bangser, 2008). Intrusive advising would be a collaborative effort between secondary and postsecondary advisors supporting first-time first-year college students, particularly students at risk, in the transition from high school to college, to ensure completion of at least 20 credits by the end of their first year of enrollment (Adelman, 2006; Vargas & Venezia, 2015).

Final Thoughts. Although the roots of secondary and postsecondary alignment are historical, recent government legislation has exacerbated the problem. *No Child Left Behind* legislation (NCLB), now *Every Student Succeeds Act* (ESSA), was designed to increase student academic preparation and achievement; however, little postsecondary input was solicited, and the standards and guidelines were not aligned with postsecondary admission requirements or academic expectations (Boser & Burd, 2009). Until an integrated P-16 system is developed with K-12, postsecondary and business community leaders who are deeply engaged in the development of standards and expectations, misalignment between secondary, postsecondary and the business community will continue to exist (Bangser, 2008).

Dual Credit and Postsecondary Preparation

As postsecondary degree attainment becomes increasingly important, finding ways for students to successfully transition from secondary to postsecondary education is essential. Dual credit, also known as concurrent enrollment, is an increasingly popular and effective program intended to increase student postsecondary outcomes and allow students to experience the rigor and pacing of college-level courses while still in high school and with access to secondary supports (Karp, 2006). The hope is that exposing students to college coursework while providing them with secondary supports will bridge the gap by increasing both secondary and postsecondary achievement and prepare students for the social and academic expectations of college. Equitable access to dual credit coursework would provide an affordable opportunity for participation by low-income and underrepresented minorities (Riehl, Henig, Wolff & Rebell, 2019). However, little research exists that examines the impact of dual credit on middle- and low-achieving students (Karp et al., 2004).

Adelman (2006) advocated for the first year of college to begin in high school, either through AP coursetaking or dual credit enrollment, with both secondary and postsecondary working together to promote student success. Research on dual credit course taking has been shown to have a positive impact on postsecondary student enrollment and degree attainment (Bailey, Hughes and Karp, 2002; Smith 2007). On average, holding ACT score, gender, income, race and ethnicity constant, concurrently enrolled students had a 22.9% increase in the likelihood of enrolling in college immediately after high school graduation and an 11.2% reduction in developmental course enrollment (Bautsch, 2014; Giani, Alexander & Reyes, 2014). Students who complete dual credit courses were more likely to graduate from high school, enroll in a four-year postsecondary institution, and persist to a degree in college (Hughes, Rodriguez, Edwards & Belfield, 2012). They were also less likely to be placed into developmental education, earned more college credits and had higher grade point averages than comparison students (Allen & Dadgar, 2012; Hughes et al, 2012).

"Education is the most powerful weapon which you can use to change the world"

Nelson Mandela (1918-2013)

President Obama and I understand that education is the key to both individual success and collective prosperity in a knowledge-based economy. It's the surest path out of poverty--and in the United States, education has long been the great equalizer, the one force that empowers people to overcome differences in power and privilege.

Arne Duncan (2012)

In general, dual credit courses have primarily been an option for well-off schools and high- performing students (An, 2013; Barnett & Stamm, 2010). In 2009, only 11% of ninth graders from high-poverty backgrounds took at least one dual credit course at some point during high school (ACT 2018). In 2008, Memphis City Schools invested in and expanded their dual credit program (Barnett & Kim, 2014). The demographics of the student body – 83% African American and 72% eligible for free and reduced lunch – were unique compared to many other dual credit programs (Barnett & Kim, 2014; Thomas, Marken, Gray & Lewis 2013). The 2011-2012 results were impressive, with 91% of students passing with a grade of C or higher (Barnett & Kim, 2014).

A study by Young, Joyner & Slate (2013) of postsecondary outcomes for Texas dual credit student found that both White and African American dual credit students had a significantly higher first-term postsecondary GPA than White nondual credit students. However, while the percentage of student participation for White, Hispanic and Asian students increased more than 10% from 2005 to 2011, the percentage of African American student participation increased by only 2% (Young, Slate, Moore & Barnes (2013). Texas, one of several states legislating dual enrollment eligibility requirements, has a dual enrollment policy that requires secondary students to score at proficient or higher on the NAEP assessment before enrolling in dual credit course work (Karp, Bailey, Hughes & Fermin, 2004).

Dual Credit Math

Although several studies report positive effects of DC course taking on postsecondary outcomes, not all courses are accessible to many secondary students. In the study of Memphis City Schools by Barnett & King (2014), only 5% of students enrolled in a dual credit math course, primarily due to postsecondary minimum ACT and grade point requirements. A Georgia study of urban early college students taking DC courses reported students were required to take a college placement exam to enroll in college-level math but not college-level English (Ramsey-White, 2012). Giani, Alexander & Reyes (2014) suggest the dual credit courses in core academic subjects, which prepare students for postsecondary college-level course work, significantly increase postsecondary outcomes. This is particularly true of enrollment in dual credit math courses based on hours earned, which has been found to positively correlate with college readiness and postsecondary degree attainment (Kim and Bragg, 2008). Dual credit math was significantly related to all six-year degree completion models and had the strongest influence on bachelor’s degree attainment of any DC course analyzed (Giani, Alexander & Reyes, 2014; Kim and Bragg, 2008). Furthermore, Kim and Bragg, 2008 found each DC math course increased the odds of bachelor’s degree attainment in six years by 60% to 90%. Speroni (2011) reported students specifically taking DC college algebra had substantial and significant gains in postsecondary enrollment and degree attainment.

The primary criteria for determining college readiness and placement in college algebra for post-secondary students are ACT/SAT cut scores and/or college placement test; however, eligibility criteria for dual credit students varies extensively by state (Karp, Bailey, Hughes & Fermin, 2004). Karp et al (2004) identify 38 states with a dual credit policy, with 29 of those states dictating student eligibility criteria often requiring a high level of academic skill (minimum ACT math subscore of 22) for dual credit participation. Three states left eligibility decisions up to postsecondary institutions, six allowed secondary institutions to determine student eligibility, and one state required institutions to work together to set eligibility requirements. Other states either do not have a state policy or only dictate eligibility requirements for age. States with multi-tiered eligibility requirements were able to increase participation in dual enrollment without lowering college standards or failing large numbers of students.

Little research exists that examines the impact of dual credit math course taking on middle- and low-achieving students (Karp et al., 2004). Furthermore, several states and postsecondary institutions include ACT/SAT cut scores as part of their eligibility criteria for dual credit students, although there is no literature available that analyzes the relationship between ACT/SAT scores and success rates for students taking college-level math on a high school campus with a high school teacher as the primary instructor. As noted by Zwick, (2002) standardized test benchmarks were created from data analysis preformed on postsecondary student outcomes and was not examined using secondary student dual credit outcomes. Extrapolation of results correlating ACT/SAT math benchmarks and college algebra passing rates for postsecondary undergraduates should be considered with caution before being applied to full-time secondary students, particularly if dual credit course work increases postsecondary preparation for underachieving students by exposing them to the rigors of college level coursework, which in turn better prepares them for the level of work expected when they begin college (Karp et al., 2004).

Summary

Current and future employment projections have established the need for more postsecondary graduates, particularly those with STEM degrees and proficiency in math and technology (Carnevale, Smith, & Strohl, 2010). A postsecondary credential/degree is essential for middle class employability, and effective programs need to be implemented to improve postsecondary degree attainment, particularly for underserved student groups (Carnevale, Smith, & Strohl, 2010). To provide enough graduates to fill future workforce projections, the disconnect between secondary and postsecondary institutions must be bridged through increased communication and collaboration, so that genuine college readiness can occur (Conley, 2007, National Research Council, 2002).

In addition, college readiness cannot continue to be measured by standardized test scores, even when combined with another measure such as high school GPA. Instead, more robust measures including both academic and nonacademic proficiencies, such as cognitive strategies, content knowledge, learning skills and techniques and transition knowledge or skills for life beyond high school, need to be considered (Conley, 2012). Far too many students continue to struggle to successfully earn GE credits, particularly in math (Adelman, 2004; Chen, 2016). Increasing degree completion and reducing the need for postsecondary remediation requires the implementation of research-based programs that prepare secondary students for the rigor and expectations of postsecondary coursework (Conley, 2007, 2012; Wang, 2013). This is particularly true for college algebra, which for many students is a barrier toward postsecondary progress and degree completion, particularly for students seeking degrees that require math proficiency (Ganga & Mazzariello, 2018; Thiel, Peterman, & Brown, 2008; Wynegar, & Fenster, 2009). Although well intentioned, developmental education programs have not sufficiently documented successful student degree progression, particularly for underprepared and underserved populations (Chen, 2016).

By its very nature, dual credit bridges the institutional gap by requiring interaction between secondary and postsecondary institutions, which in turn directly and indirectly influences both academic and nonacademic proficiency (Karp, 2013). Equitable access to dual credit coursework combined with faculty/teacher training and support would provide an affordable opportunity for participation by low-income, first generation and underrepresented minorities to better prepare for successful college matriculation (Riehl, Henig, Wolff & Rebell, 2019; Venizia & Jaeger, 2013). With the research clearly showing the positive impact of dual credit course work, specifically college algebra, on postsecondary outcomes it is evident that increased access to dual credit mathematics is an important means of preparation for postsecondary success and the 21st century work force (Speroni, 2011). Postsecondary institutions should consider 1) redesigning college algebra to include noncognitive aspects of student learning and 2) finding ways to increase access to dual credit college algebra.

Chapter 3: METHODOLOGY

Background

In 2006, the University of Kentucky (UK) implemented a program titled “Access to Algebra” (A2A). This program was funded by a National Science Foundation (NSF) grant and was part of the Appalachian Mathematics and Science Project (AMSP) designed to increase STEM opportunity and achievement in Appalachian districts and to offer rural high school students an opportunity to earn college algebra credits from both their high school and UK. High school students worked and primarily interacted with their on-site high school mathematics teachers while UK faculty assumed the responsibilities of training, professional development, testing and course design. The course was taught on participating high school campuses and facilitated by on-site high school teachers. The high school teachers participated in weekly seminars to review course materials and instructional approaches to upcoming topics. The course included machine-graded homework which was stored and maintained on the Web Homework System sever located at UK. The online homework problems were created using Maple software, and each homework set included introductory videotaped lectures along with video tutorials attached to each individual homework problem.

In the fall of 2009 Kentucky State University (KSU), a small liberal arts university and part of the 1893 land grant initiative of Historically Black Colleges and Universities, created a dual credit college algebra course modeled after the original A2A program at UK and developed under the oversight of the KSU mathematics department. The A2A program at KSU was funded by the Office of Regional Stewardship and implemented in response to Senate Bill 1, which was signed into law on March 26, 2009, and intended to increase college readiness and reduce postsecondary remediation rates.

All the key elements of the original UK model were kept in the adoption. Student learning and performance was assessed through four paper and pencil exams, a cumulative final exam, one project, 12 mastery-based online homework sets with corresponding paper and pencil quizzes, student presentations and collaboration. The supervising secondary math teacher covered pre-requisite content, answers questions, gives feedback, monitors student progress, and provided support and encouragement for students enrolled in the online course. The KSU faculty members provided professional development and training, rigorous college level math content, assessments, student learning outcome measurements, and semester scheduling in alignment with similar courses offered on the university campus.

Although the course was online, a certain amount of additional teacher support was built in due to the five-day-per-week direct teacher contact at the secondary level. Students were encouraged to collaborate and assist each other, present solutions to more difficult problems to their peers and explain their reasoning in paragraph form when prompted. High school math teachers supplemented the online lecture videos by providing brief, whole-class or individual discussions and activities to reinforce and prepare students for the content covered in each weekly homework set. The online homework and corresponding video tutorials attached to each homework set allowed for more flexible, self-paced learning and increased targeted teacher assistance (Bain 2004). In turn, this enabled the facilitating teacher to help students on an individual, as-needed basis. Thus, the collaborating high school teacher was free to offer extra assistance to struggling students, while more prepared students could move ahead. In addition to increasing student academic knowledge, the course was designed to remediate mathematical skill deficits and increase noncognitive levels of college readiness through implementation of effective pedagogical methodologies. Ideally, even students who did not pass the A2A college algebra course would be significantly more prepared for undergraduate college/university math coursework.

The course could be taught during one semester or over the course of a year, using the fall semester for pre-requisite preparation or reinforcing difficult content. Some secondary schools chose to offer the course twice during the academic year, once in the fall and again in the spring, while other schools preferred a yearlong approach with the fall semester dedicated to preparation and actual course enrollment occurring in the spring semester. The pace of the machine-graded homework and testing windows remained similar to the corresponding one-semester course taught on the university campus, although the content and pace of the course could be modified somewhat to accommodate the high school semester or trimester schedules. Late assignments were not accepted without a documented excuse.

The A2A college algebra program was unique in that the only prerequisite requirement for enrollment in the dual credit course was a passing grade of C or higher in Algebra 2. Some high schools utilized additional considerations, such as counselor/teacher recommendations, HS GPA and work ethic/persistence when recommending student placement, particularly during initial implementation. The course was provided at a reduced cost to lessen the financial burden for low income schools and students. In other words, the A2A program was designed to provide equitable access to a rigorous college algebra curriculum, leading to an increase in college- level math preparation and a subsequent increase in confidence and attainment of college-level math credit.

Program Advantage

Currently, most public postsecondary institutions in Kentucky require a minimum ACT math cut score, or successful passing of a college algebra placement exam, as a prerequisite for enrollment in dual credit college algebra. The ACT (or equivalent SAT) cut score of 21 or 22, based on ACT benchmark recommendations, is the same prerequisite requirement for first-time freshmen college algebra placement and is similar to cut scores used by other postsecondary institutions across the country (Hoyt & Sorenson, 2001). In contrast, the A2A program does not require a minimum standardized test score as a prerequisite for participation in dual credit college algebra. The only prerequisites required for enrollment in the dual credit college algebra course is a C or higher in Algebra 2. Students who might otherwise be excluded from enrolling in the dual credit course (and subsequently at the undergraduate level) are allowed access to the college level material.

Students who pass the course gain college level math credit and potentially avoid placement in a developmental math course. A grade of C or better will often fulfill a gateway math course requirement and/or pre-requisite for majors such as STEM and MT degrees that require proficiency in college algebra as part of the math course progression. In some cases, students who pass the college algebra course with a D or better will have fulfilled their GE math requirement for degrees that do not require college algebra as a core math course. As an incentive to encourage students to persist until the end of the semester and increase their college math preparation, the last day to drop with a W is extended through the last week of the semester. Students who do not pass the course can take a college algebra placement exam, which if passed allows them to enroll in a credit-bearing math course as an undergraduate.

Theoretically, a students' competency with the college algebra curriculum should have already been assessed, since the statewide the Common Core Algebra 2 standards generally cover the same mathematical content included in the standard college algebra course curriculum: solving equations and inequalities, including linear, rational, quadratic, absolute value, exponential and logarithmic; developing problem solving techniques; the algebra of functions and their graphs; properties and graphs of polynomial, rational, exponential and logarithmic functions. (http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf). However, in spite of the similarities in content, an achievement divide appears to exist between high school Algebra 2 and postsecondary college algebra, which is well documented by the high postsecondary college algebra failure rates (Thiel, Peterman, & Brown, 2008). The differences in achievement appear to be more a result of differences of course expectations, depth of knowledge, pace, and the use of machine-graded homework, rather than content (Adelman, 2004, Conley, 2007). Students enrolled in the A2A college algebra course and other dual credit college algebra courses across the state, are exposed not only to college level math content but to the rigor, depth of knowledge, fast pace, and expectations of a college-level math course.

The Experiment

This quantitative study was based on a quasi-experimental design involving student participation in dual credit college algebra courses offered from the fall of 2009 through the spring 2019. This investigation is a quasi-experimental study with a well-defined but self-selected treatment group, and a non-experimental control group. The researcher was neutral to the experiment (i.e., the researcher did not have a direct relationship with the students). A2A recruitment of participating high schools (and hence students within participating schools) was voluntary and occurred primarily through word of mouth. Likewise, students enrolled in dual credit college algebra coursework offered at other postsecondary institutions did so voluntarily and without randomization. Some screening efforts were made to select eligible students for data analysis in this study. First, only graduating secondary seniors were compared and participation by students in lower grades was excluded. Second, students without a junior year ACT/SAT math subscore were excluded from the study (at the time of the study, all Kentucky students are required to take the ACT at the end of their junior year.)

This study relied on extant performance and transcript data from Kentucky Center for Statistics (KYSTATS) to compare the secondary and postsecondary records of high school seniors from fall 2009 through spring 2019. KYSTATS collects and links student demographics, transcripts and performance data for pre-school, elementary, middle, high school, college and career across the state of Kentucky. The data examined included secondary school and student information regarding gender, age, race/ethnicity, ACT math and English subscores as well as high school GPA at graduation. School variables consisted of Title 1 status, school type (metro, micro, rural). Postsecondary information provided included enrollment, first-year GPA, hours attempted, hours earned, degree completion and time to degree, and type of degree or certificate earned.

The Sample

The initial overall sample contained 446,401 students who completed their senior year of high school and earned a high school diploma. Students who took dual credit from other postsecondary programs were also identified and included as part of the treatment group. Among the overall sample, a total of 17,728 high school seniors enrolled in at least one dual credit college algebra course outside of the A2A program, and 4741 students from 32 high schools were part of the A2A dual credit program including 9 metropolitan area schools, 16 micropolitan area schools and 7 rural schools. The overall dual credit college algebra samples were reduced due to missing high school level transcript data (e.g., standardized test scores, final high school GPA, SES) and missing postsecondary performance and transcript records. As a result, the final overall sample size was 198,221 with the final A2A sample size composed of 14,301 high school seniors who enrolled in dual credit college algebra and 183,920 non-college algebra takers. High school students who did not enroll in dual credit college algebra course at any postsecondary institution formed the natural control cohort. To make students in this cohort comparable to A2A students, a special control cohort was identified through a statistical matching technique often referred to as propensity score matching (PSM).

In this study, postsecondary outcomes for high school seniors from across the state who participated in A2A college algebra were compared with those who did not enroll in a dual credit college algebra course. Students from both cohorts were longitudinally tracked through their postsecondary career and the results provide a longitudinal analysis of the long-term postsecondary outcomes of secondary students enrolled in at least one dual credit college algebra course between fall 2009 through spring 2019.

The Measures

Control Variables. Because strict academic requirements are imposed on dual credit participation, enrollment in dual credit courses is generally limited to higher achieving students (An, 2013). The effect of enrollment in dual credit college algebra on both high and lower achieving students was analyzed using HS achievement variables shown to impact postsecondary success which included math course taking history, HS GPA, and standardized test scores (Adelman, 1999, 2004). College readiness was determined by, 1) reported high school college readiness indicators and 2) junior year standardized test results. Reported high school mathematics college readiness as defined by the Kentucky Department of Education (KDE) and the (CPE) was determined by math ACT (or SAT equivalent) score with 0 = not college ready (math ACT score < 19) and 1 = college math ready (math ACT score ≥ 19). College algebra readiness as defined by the KDE and CPE was also determined by math ACT (or SAT equivalent) score with 0 = not college algebra ready (math ACT score < 22) and 1 = college algebra ready in math (math ACT score ≥ 22). High school GPA was measured on four-point scale with an "A" represented by a 4.0 representing a "F" represented by 0.0.

Non-academic control variables shown to correlate with dual credit taking, mathematics achievement and postsecondary success (e.g. SES, race and ethnicity) were included as control variables since minority students and low SES students are less likely to participate in dual credit course work, particularly in dual credit math and are less likely to successfully complete a postsecondary degree (Adelman, 2004; An, 2013; Riehl, Henig, Wolff & Rebell, 2019; Meade & Hoffman, 2007). Race and ethnicity coding was categorical and based on the data provided by KYSTATS with Hispanic or Latino = H, Native Hawaiian or Pacific Islander = P, Other = O, American Indian = I, Asian = A, or African American = B, 2 or more races = M and White = W. Student SES will be measured by transcript reported free and reduced lunch eligibility data with 0 = Paid and 1 = Free or reduced. Secondary school characteristics were also considered for each student including the type of school attended and the secondary school's Title 1 status. The type of school was based on the community statistical area as defined by the US Census with categories of rural (= 0), micropolitan, (= 1) and metropolitan (= 2). A secondary school Title 1 eligibility was coded as 0 = poverty level (PVL) $< 35\%$ (not eligible for assistance) and 1 = PVL $> 35\%$ (eligible for school wide or targeted assistance). Additional control variables used included gender as a dummy variable (Male = 1, Female = 0).

Dependent Variables. The research questions in this study explore the differences in postsecondary outcomes between dual credit college algebra participants and non-participants (controlling for student demographic and academic achievement during high school). These postsecondary outcomes were the dependent variables. The first research question compares postsecondary enrollment immediately following graduation enrollment in two-year and four-year postsecondary institution with enrollment defined as initial full-time undergraduate attendance at a two- or four-year institution during the fall immediately following graduation. Initial full-time undergraduate enrollment was coded as (Yes = 1, No = 0).

The second research question compared 1) first-year persistence, 2) first year GPA, 3) time to degree and 4) certificate, associate or bachelor degree completion, and 4) degree attainment in a STEM or a math/technology competency-based field. First year persistence was defined as the number of credit hours in which a student enrolled as a fist-time undergraduate and was dummy coded as (< 24 credit hours = 0 and ≥ 24 credit hours = 1). Postsecondary GPA was continuous, defined for fall and spring semesters on a four-point scale from 0.0 through 4.00. Time to degree, beginning immediately after postsecondary enrollment, is continuous and measured by the number of academic years (fall and spring) until graduation. Certificate completion or completion of a < 2-year diploma was a dummy variable, operationalized (Yes = 1, No = 0). Completion of an associate degree or a bachelor's degree (or higher) were both dummy variables (Yes = 1, No = 0). Choice and attainment of degree in STEM or a math/technology competency-based field were dummy variables (Yes = 1, No = 0).

Analysis

One unique characteristic of the current experimental design was the lack of a control group. When there is well-defined but self-selected treatment group, a control group is necessary to control for selection bias (Blundell, Dearden & Sianesi, 2005). A simple strategy would be to designate the control group as the non-participating students in each high school graduating senior cohort during each year of dual credit college algebra participation, selecting only students who were eligible or qualified to enroll in A2A or other dual credit college algebra programs but did not. However, this approach still allows for too many unknown confounders in the control group, which could cause the results to be biased due to systematic differences between the treatment and control group (Dehejia & Wahba, 2002). Even if extensive background information was known for students in each cohort, it would be statistically impossible to account for the effects of potential unknown confounding variables (An, 2013).

Propensity Score Matching (PSM) attempts to replicate an experimental study after the fact by matching students in the control group who have similar observable characteristics (confounding variables or covariates) with students in the treatment group based on their propensity score which represents the conditional probability of a student being chosen to participate in dual credit college algebra (An, 2013; Blundell et al., 2005; Rosenbaum and Rubin, 1984). For example, if a student has a propensity score of 0.2, they have a 20% chance or being part of the college algebra treatment group given their covariate values.

PSM was originally developed for use in biomedical research to create an after the fact quasi experimental structure allowing for plausible causation in non-randomized studies (Fan & Nowell, 2011; Guo & Fraser, 2014). By matching individuals in both cohorts using observed confounding variables (covariates), the argument for causality is strengthened and selection bias reduced (Randolf, Falbe, Manuel & Balloun, 2014). The primary goal of PSM is to balance all the covariates for the matched groups by estimating propensity scores, hence successful PSM depends on finding a large group of non-participants who have several similar pretreatment covariates (Caliendo & Kopeinig 2008).

Covariates which impact the probability of participation must be chosen carefully and have no influence on treatment effects for the outcome variables (Rosenbaum and Rubin, 1984). Too many covariates can cause difficulties with matching and increase variability, and too few covariates can exclude important cofounders. (Heckman and Robb, 1985). Differences in postsecondary outcomes between A2A and other dual credit college algebra participants and non-participants could be influenced by individual pretreatment differences, so it was important to control for potential sources of biases by finding students with similar academic and family backgrounds (Blundell et al., 2005). For example, research has shown that students from higher SES backgrounds and better schools often demonstrate higher gains in postsecondary outcomes than students from lower SES backgrounds and lower performing schools so SES is a potential cofounder and was included as one of the covariates used for matching (Deming, Hastings, Kane & Staiger, 2014; Kena, Musu-Gillette, Robinson, Wang, Rathbun, Zhang, Wilkinson-Flicker, Barmer & Valez, 2015). Race was also chosen as a covariate since studies have shown that African American and Hispanic students 50% less likely to earn a bachelor's degree than White students (Callan et al, 2006). PSM relies on a conditional independence assumption that all observable confounding variables have been included as covariates, hence differences in postsecondary outcomes between students in the treatment group and the control group are sufficiently controlled so that any remaining differences can be attributed to the actual treatment effect (An, 2013; Blundell et al., 2005; Caliendo & Kopeinig, 2008).

Procedurally, for each dependent variable, A2A participants and non-participants will be matched based on student academic and demographic background discussed in the previous section (Caliendo & Lipeninig, 2006). Along with individual level variables, students will be matched on essential school level characteristics to control for differences in school demographics. Through this procedure, PSM will help to identify groups of comparable students and evaluate am differential effects on postsecondary outcomes.

As with any research method there are advantages and disadvantages to using PSM. Some advantages of PSM are 1) it removes the effects of identifiable covariates which could influence treatment outcomes, 2) it also easier to match more than one covariates compared to multi-linear regression, 3) it is more straightforward than a large multiple regression model and 4) it creates a quasi-experimental structure which provides an opportunity to investigate causation when randomization is not possible or feasible (Guo & Fraser, 2014). Some disadvantages are 1) A certain amount of overlap must occur between the control and treatment group, or variable biases can occur, 2) the magnitude of the effects of the covariates on the subjects cannot be measured, 3) covariate effects on outcomes cannot be measured and 4) PSM assumes conditional independence or unconfoundedness which is the assumption that there are no unknown covariates affecting the outcomes (Caliendo & Kopeinig, 2008; Guo & Fraser, 2014).

Overall, PSM combined with linear regression will be employed as the chief statistical technique to determine treatment effects for the current DC college algebra experimental design. The validity of the PSM method relies on both high-quality data that is sufficiently rich, and the appropriateness of the matching variables chosen (Caliendo & Kopeinig, 2008; Blundell et al, 2005). The comprehensive database provided by Kentucky Center for Statistics adequately met this requirement since the database contains all demographic and academic background information identified throughout the literature review as important to students who were eligible for participation in A2A. Finally, the STATA platform will be used to carry out the PSM and regression analyses that assess treatment effects.

Chapter 4: RESULTS

Background

The purpose of this research was to examine the effect of dual credit college algebra enrollment on postsecondary enrollment, persistence, GPA, and degree outcomes. More importantly, this study examined the postsecondary impact of allowing high school students considered underprepared for college algebra to enroll in a credit-bearing college algebra course with the only prerequisite a grade of C or higher in Algebra II. As discussed in chapter 3, extant data from KYSTATS were aggregated into one data set with demographic and academic information on each student, including A2A participants and other students who took dual credit college algebra their senior year in high school. This chapter explains the findings of the study and the results of the research questions:

1. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school increase the likelihood of enrollment immediately following graduation in both two-year and four-year postsecondary education?
2. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school affect the following:
    a. Postsecondary first year persistence?
    b. Postsecondary first year GPA?
    c. Postsecondary time to degree and degree completion?
    d. Degree attainment in a STEM or math/technology competency-based field?

Students who enrolled in dual credit college algebra from 2009 through 2019 comprised the treatment group, and students who graduated from high school without taking college algebra during that same time period were the sample used for propensity score matching. The analysis began by collecting and screening data from KYSTATS, running propensity score matching based on the covariates, then conducting a regression analysis on the matched cohorts. Propensity score matching was conducted using STATA followed by linear regression on the matched subjects, comparing postsecondary outcomes for students who took dual credit college algebra their senior year and those who did not take this course while in high school. STATA was also used for the linear regression analysis. The results of the propensity score matching and linear regression analysis on the matched groups were used to answer the research questions.

The secondary data from KYSTATS were aggregated into one data set using R, resulting in 440,564 unduplicated high school students and 29 variables. The aggregated data were then merged with postsecondary student data for a total of 440,702 students: 21,656 of whom took dual credit college algebra and 419,046 who were non-participants. The data were again screened for missing data, outliers, and collinearity. Five subjects from the control group were found to have GPAs outside of the designated range, and one subject with an English ACT > 36 was removed. No other anomalies or outliers were found in the remaining data. After removing students with missing covariate data, data preparation was completed resulting in a total of 198,221 students: 14,301 college algebra takers and 183,920 non-participants. Fourteen independent variables remained as covariates: gender, race and ethnicity (White, African American, Hispanic, Asian), student free/reduced lunch eligible, school free/reduced lunch eligible, census size (rural, micropolitan, metropolitan), high school GPA, junior ACT English score, and junior ACT math score. Individual frequency and percent descriptive statistics for these independent variables can be found in appendix A and B. A preliminary analysis revealed white students comprised for over 85% of the total sample, and other individual race and ethnicity categories accounted for 9% or less. To address this unequal distribution, a bimodal category for race and ethnicity was created as a replacement for the original 4 categories and dummy coded (0 = white, 1 = non-white). Rural census size was removed as a separate variable and census size categories were recoded as micropolitan (0 = rural, 1= micropolitan) and metropolitan (0 = rural, 1= metropolitan). Finally, the variable "senior academic year" was introduced to control for differences in high school graduation year and time left to complete a degree before spring 2019. Because students graduating from high school after the 2015-2016 academic year would have 3 years or less to complete a degree, senior academic year was dummy coded (0 = before 2016, 1 = during or after 2016). The final covariate list consisted of senior academic year, gender, race and ethnicity, student free/reduced lunch eligible, school free/reduced lunch eligible, census size (micropolitan and metropolitan), high school GPA, junior ACT English score, and junior ACT math score.

Descriptive Statistics

Table 2 displays the demographics associated with each covariate. Results of the analysis showed that, in the < 22 ACT group, 30% of students without college algebra and 39% with college algebra graduated before 2016. Thirty-eight percent and 51% of students without and with college algebra, respectively, in the ≥ 22 ACT group graduated before 2016. Forty two percent of the students in the ≥ 22 ACT group without college algebra were males, compared with 33% in the < 22 ACT group with college algebra. For students in the ≥ 22 ACT group, 51% of without college algebra students were males compared to 43% in the with college algebra group. For the < 22 ACT group, a substantial percentage (85%) of the students without college

Table 2

Descriptive Statistics of Independent Variables for ACT Math Subgroups Prior to Matching

	Jr Math ACT Subscore < 22				Jr Math ACT Subscore ≥ 22			
	No Treatment (N = 131,476)		College Algebra Treatment (N = 4,395)		No Coll Alg (N = 61,388)		College Algebra Treatment (N = 9,906)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Senior Academic Year [a]	.30	.46	.39	.49	.38	.48	.51	.50
Gender (0 = female, 1 = male)	.42	.49	.33	.47	.51	.50	.43	.50
Race/Ethnicity (0 = white, 1 = non-white)	.15	.36	.12	.32	.07	.26	.06	.24
Free/Reduced Lunch (0 = paid, 1 = free/reduced)	.48	.50	.37	.48	.26	.44	.30	.46
School Title 1 Status (0 = < 35% PVL, 1 = > 35% PVL) [b]	.59	.50	.71	.45	.54	.50	.77	.42
Rural [c]	.28	.45	.28	.45	.19	.39	.31	.46
Micropolitan	.22	.41	.32	.47	.22	.41	.23	.42
Metropolitan	.50	.50	.40	.49	.60	.49	.47	.50
Final High School GPA	2.96	.57	3.36	.44	3.49	.46	3.60	.38
Jr ACT English Subscore	17.85	4.45	20.53	3.85	25.26	4.77	25.06	4.42
Jr ACT Math Subscore	17.22	2.0	18.92	1.68	25.29	2.79	24.77	2.22

Note: [a] For senior academic year (0 = 2009 through 2015 and 1 = 2016 through 2019). [b] PVL = Poverty Level. [c] Rural, Micropolitan and Metropolitan refer to school statistical area census size.

algebra were white compared to 88% of the treatment group. For the ≥ 22 ACT group, 93% and 94% of students were white for the without and with college algebra groups respectively. Half of the without college algebra students (48%) and with college algebra (37%) were eligible for free or reduced lunch in the < 22 ACT group. The ≥ 22 ACT group was similar with 26% of students without college algebra and 30% of students with college algebra eligible for free or reduced lunch. More than half of students in the < 22 ACT group without college algebra (59%) and with college algebra (71%) attended schools which met the 35% poverty level threshold for Title 1 assistance and were eligible to receive targeted or school wide assistance. A similar proportion of students without college algebra (54%) and with college algebra (77%) in the ≥ 22 ACT group attended schools Title 1 eligible for targeted or school wide assistance. For students in the < 22 ACT group, most students without college algebra attended metropolitan (50%) followed by rural (28%) and micropolitan (22%) statistical area schools. Students in the same ACT group with college algebra attended metropolitan (40%) followed by micropolitan (32%) and rural (28%) statistical area schools. Similar results were found for the ≥ 22 ACT group among the without college algebra cohort with a majority attending metropolitan schools (60%) followed by micropolitan (22%) and rural (19%). Students with college algebra in the same ACT group attended metropolitan schools (47%) at a higher rate than rural (31%) and micropolitan (23%). Final high school GPA was similar within ACT groups. Students without college algebra from the < 22 ACT group had a lower mean GPA of 2.96 compared to 3.36 for students with college algebra. Likewise, students in the ≥ 22 ACT group without college algebra had a somewhat lower mean GPA of 3.49 compared to 3.60 for students with college algebra. Students without college algebra in the < 22 ACT group had a mean English ACT score 2.7 points lower (17.85) compared to students with college algebra (20.53). For the ≥ 22 ACT group, students with college algebra (25.26) and without college algebra (25.06) had similar mean ACT English scores. For the < 22 ACT group, the mean ACT math score for students without college algebra (17.22) was 1.7 points lower than the mean ACT math score for students with college algebra (18.92). In contrast, students in the ≥ 22 ACT group without college algebra had a mean ACT math score (25.29) that was 0.52 points higher than the mean score for students with college algebra (24.77).

Table 3 displays the correlation analysis for non-college algebra takers. Most of the correlations in Table 3 were statistically significant. The range of correlations was from -.64 to .52. Correlations for a few pairs were near zero (e.g., between gender and race/ethnicity). The strongest correlation was -.64 between micropolitan and metropolitan. Although some correlations may not make much practical sense, the goal of this correlation analysis was to ensure the absence of collinearity (i.e., variables that were so highly correlated that they may be identical in terms of measurement). Therefore, Table 3 does not indicate any serious concerns.

Table 4 displays the correlation analysis results for college algebra takers. A majority of the correlations in Table 4 were also statistically significant with a broad range of correlations from -.56 to .42. Similar to Table 3, correlations for a few pairs of variables were near zero (e.g., between gender and race/ethnicity). The strongest correlation was -.56 between micropolitan and metropolitan. The results of the correlation analysis for Table 4 did not indicate the presence of highly correlated variables.

Table 3

Correlations of Sociodemographic Variables and Academic Achievement for Non-Dual Credit College Algebra Takers.

Variable		1	2	3	4	5	6	7	8	9	10
	N	61,388	61,388	58891	61,388	61,388	61,388	61,388	61,388	61,388	61,388
1. Senior Academic Year	131,476	—	-.02**	.01	.05**	.43**	.00	.01	.05**	.06**	.04**
2. Gender	131,476	-.01**	—	-.00	-.02**	-.01*	-.01	.02**	-.28**	-.15**	.09**
3. Race/Ethnicity	125,029	.02**	.02**	. —	.13**	-.01**	-.07**	.14**	-.08**	-.08**	-.03**
4. Free/Reduced Lunch	131,476	.06**	-.05**	. 20**	—	.13**	.04**	-.12**	-.15**	-.16**	-.15**
5. School Title 1 Status	131,476	.42**	-.01*	-.00	.15**	—	.16**	-.27**	.08**	-.01**	-.04**
6. Micropolitan	131,476	-.00	-.01**	-.10**	.00	.06**	—	-.64**	.08**	.02**	-.03**
7. Metropolitan	131,476	-.00	.01**	.26**	-.10**	-.20**	-.53**	—	-.16**	.02**	.10**
8. Final High School GPA	131,476	.06**	-.23**	-.17**	-.18**	.05**	.03**	-.11**	—	.41**	.35**
9. Jr ACT English Subscore	131,476	.07**	-.13**	-.20**	-.19**	-.01**	.02**	-.00	.40**	—	.50**
10. Jr ACT Math Subscore	131,476	-.01	.02**	-.14**	-.20**	-.07**	.01**	.05**	.41**	.52**	—

Note: $^{*}p < .05$, $^{**}p < .01$. Statistics for math ACT scores < 22 and math ACT scores ≥ 22 are reported in the bottom left and top left of the table respectively. Categorical data was dummy coded as senior academic year (0 = 2009 through 2015 and 1 = 2016 through 2019), gender (male = 0 and female = 1), race/ethnicity (0 = white and 1 = not white), free and reduced lunch (0 = paid and 1 = free or reduced), school title 1 status based on schoolwide poverty level (0 = not eligible for assistance and 1 = eligible for Title 1 assistance), rural, micropolitan and metropolitan census size (0 = no and 1 = yes). Final high school GPA, junior ACT English subscore and junior ACT math subscore are continuous variables.

Table 4

Correlations of Sociodemographic Variables and Academic Achievement for Dual Credit College Algebra Takers.

Variable		1	2	3	4	5	6	7	8	9	10
	N	9,906	9,906	9,906	9,906	9,906	9,906	9,906	9,906	9,906	9,906
1. Senior Academic Year	4,395	—	.00	.01	.01	.39**	-.00	.07**	.03**	.06**	.06**
2. Gender	4,395	-.03*	—	-.05**	-.02*	-.00	-.01	.01	-.24**	-.16**	.12**
3. Race/Ethnicity	4,395	.05**	-.05**	. —	.11**	-.00	-.05**	.14**	-.09**	-.08**	-.05**
4. Free/Reduced Lunch	4,395	.03*	-.05**	.19**	—	.08**	.01	-.10**	-.10**	-.11**	-.09**
5. School Title 1 Status	4,395	.41**	-.02	-.00	.07**	—	.08**	-.18**	.07**	.04**	.06**
6. Micropolitan	4,395	-.08**	.03*	.01	-.04**	.05**	—	-.51**	.02	.03**	.01
7. Metropolitan	4,395	.12**	-.01	.13**	-.07**	-.17**	-.56**	—	-.18**	-.02	.03**
8. Final High School GPA	4,395	.07**	-.24**	-.11**	-.08**	.12**	-.09**	-.12**	—	.38**	.28**
9. Jr ACT English Subscore	4,395	.14**	-.13**	-.09**	-.06**	.08**	-.08**	.01	.29**	—	.42**
10. Jr ACT Math Subscore	4,395	.01	.05**	-.11**	-.03	.06**	-.13**	.05**	.23**	.35**	—

Note: $^{*}p < .05$, $^{**}p < .01$. Statistics for math ACT scores < 22 and math ACT scores ≥ 22 are reported in the bottom left and top left of the table respectively. Categorical data was dummy coded as senior academic year (0 = 2009 through 2015 and 1 = 2016 through 2019), gender (male = 0 and female = 1), race/ethnicity (0 = white and 1 = not white), free and reduced lunch (0 = paid and 1 = free or reduced), school title 1 status based on schoolwide poverty level (0 = not eligible for assistance and 1 = eligible for Title 1 assistance), rural, micropolitan and metropolitan census size (0 = no and 1 = yes). Final high school GPA, junior ACT English subscore and junior ACT math subscore are continuous variables.

Since one of the principle goals of this research was to measure the effect of dual credit college algebra on postsecondary outcomes for low achieving students, the researcher separated the treated and untreated cohorts into groups based on junior ACT math subscore. Students meeting the college algebra benchmark of math ACT ≥ 22 were dummy coded with a 1 and students with a math ACT < 22 were dummy coded as 0. The four groups consisted of college algebra takers with a math ACT < 22 (*N* =4,395), college algebra takers with a math ACT ≥ 22 (*N* = 9,906), non-college algebra takers with a math ACT < 22 (*N* =125,029), and non-college algebra takers with a math ACT ≥ 22 (*N* =58,891). Splitting the treatment group into separate ACT groups caused a reduction in sample size but was necessary to achieve meaningful results.

The data were then examined for missing dependent variables (postsecondary outcomes). The researcher found that missing postsecondary outcomes were inconsistent across subjects. Removing all missing dependent variables resulted in a 66% reduction in the size of the treatment groups. Because there were significant missing data in three of the degree outcome variables (time to degree, type of degree, and choice of degree field), the researcher analyzed the postsecondary outcomes individually. Data were segregated into four dependent variable groups (e.g., postsecondary enrollment, persistence, GPA, and degree outcomes), and a separate analysis was run on each postsecondary outcome. Students with missing data for a given postsecondary outcome were removed, and PSM was conducted on the remaining subjects. Table 5 illustrates the distribution of students in each dependent variable group.

Table 5

Final distribution of students among college outcomes (N = 198,221)

		< 22 Math ACT		≥ 22 Math ACT	
	N	untreated	treatment	untreated	treatment
Initial Enrollment	198,128	125,006	4,364	58,889	9,869
First Year Persistence	198,157	125,029	4,368	58,891	9,869
First Year GPA	158,708	97,809	3,485	50,463	6,951
Degree Outcomes	72,628	42,614	1,660	24,968	3,386

The next step was to complete a propensity score matching analysis, details of which can be found in appendix C and D. After propensity matching was completed, descriptive statistics for postsecondary outcomes between dual credit college algebra takers and non-dual credit college algebra takers were analyzed using SPSS. The results are shown in Table 6.

For the < 22 ACT group, students with college algebra enrolled in a postsecondary institution immediately following high school graduation at a higher rate (88%) than students without college algebra (78%). Ninety-four percent of students with college algebra in the ≥ 22 ACT group enrolled in a postsecondary institution immediately following high school compared to the without college algebra students who enrolled at a rate of 91%. First year persistence was higher for the without college algebra students in both ACT groups. In the < 22 ACT group, 78% of without college algebra students persisted compared to 70% of with college algebra students. In the ≥ 22 ACT group, 50% of without college algebra students persisted compared to 47% of with college algebra students. First year postsecondary GPA was similar within ACT groups. Students without college algebra from the < 22 ACT group had a lower mean GPA of 2.69 compared to 2.73 for students with college algebra. Likewise, students in the ≥ 22 ACT group without college algebra had a somewhat lower mean GPA of 3.02 compared to 3.03 for students

Table 6

Descriptive Statistics for Postsecondary Outcomes After Matching

	Jr Math ACT Subscore < 22				Jr Math ACT Subscore ≥ 22			
	No Treatment		College Algebra Treatment		No Treatment		College Algebra Treatment	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
PS enrollment immediately following graduation (0 = no and 1= yes)	.78	.412	.88	.33	.91	.29	.94	.24
Postsecondary first year persistence (0 = no and 1 = yes)	.78	.412	.70	.46	.67	.47	.57	.50
Postsecondary first year GPA	2.69	1.01	2.73	.94	3.02	.92	3.03	.87
Postsecondary time to degree	4.02	1.46	3.85	1.41	4.0	1.14	3.76	1.11
Certificate or diploma < 2 years (0 = no and 1 = yes)	.13	.34	.11	.32	.06	.25	.09	.29
Associate degree or 2-3-year diploma (0 = no and 1 = yes)	.26	.44	.25	.44	.18	.38	.18	.39
Bachelor degree or higher (0 = no and 1 = yes)	.60	.49	.63	.48	.76	.43	.72	.45
Postsecondary STEM or MT degree field (0 = no and 1 = yes)	.29	.45	.23	.42	.33	.47	.27	.45

Note: For degree completion (0 = no degree and 1 = associate or bachelor's degree). First Year GPA and Time to Degree were continuous variables with college algebra. Students without college algebra in the < 22 ACT group's mean time to degree was 4.02 years compared to students with college algebra who graduated on average in 3.85 years. Similarly, for the ≥ 22 ACT group, students with college algebra graduated on average in 3.76 years compared to without college algebra students who graduated on average in 4.0 years. The proportion of students in the < 22 ACT group who earned a postsecondary certificate or 1-year diploma in place of a degree was 13% for those without college algebra and 11% for those with college algebra. The results were reversed in the ≥ 22 ACT group with fewer students without college algebra (6%) completing a certificate or 1-year diploma than those with college algebra (9%). Associate degree attainment was similar within ACT groups. Twenty-six percent of students without college algebra from the < 22 ACT group completed an associate degree compared to 25% of students with college algebra. Students in the ≥ 22 ACT group without college algebra had a slightly lower associate degree completion rate of 38% compared to 39% for students with college algebra. Bachelor's degree attainment proportions were reversed between the two ACT groups: fewer students in the < 22 ACT group without college algebra completed a bachelor's degree or higher (60%) compared to their with college algebra counterparts (63%). In contrast, more students without college algebra (76%) from the ≥ 22 ACT group completed a bachelor's degree or higher compared to the with college algebra students (72%). For students in the < 22 ACT group, 29% without college algebra completed a STEM or MT degree compared to 23% without college algebra. Similarly, for the ≥ 22 ACT group, more students without college algebra (33%) completed a STEM or MT degree compared to students with college algebra (27%).

To check for the presence of highly correlated variables, a correlation analysis was conducted on the dependent variables after matching. Table 7 illustrates correlations between matched dependent variables for non-college algebra takers in both the < 22 math ACT and ≥ 22 math ACT groups. Most of the dependent variable correlations were statistically significant. The range of correlations was from -1.00 to .55. Correlations for a few pairs were near zero (e.g., between postsecondary STEM or MT degree field and postsecondary first year persistence). The strongest correlation was -.82 between associate degree or 2-3-year diploma and bachelor degree or higher. The results of the correlation analysis for Table 7 did not indicate the presence of variables highly correlated to a level that would be a source of concern.

Table 8 shows the correlation analysis between matched dependent variables for college algebra takers in both the < 22 math ACT and ≥ 22 math ACT groups. Similar to the results in Table 7, a majority of correlations were statistically significant. The range of correlations was from -1.00 to .60, and correlations for a few pairs were near zero (e.g., between postsecondary STEM or MT degree field and postsecondary enrollment immediately following graduation). The strongest correlation was -.77 between associate degree or 2-3-year diploma and bachelor degree or higher. None of the variables in Table 8 had a level of correlation that would be a source of concern.

Linear regression was used to analyze the matched groups and measure the correlation in postsecondary outcomes between students with < 22 math ACT who participated in dual credit college algebra and their nonparticipating matched counterparts. The same analysis was done for students with ≥ 22 math ACT. Cohen (1988) has provided benchmarks to define effect size (eta squared) as small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), and large ($\eta^2 = 0.14$) effects. Table 9 displays the results of the regression analysis.

Table 7

Correlations of Postsecondary Outcomes for Non-Dual Credit College Algebra Takers After Matching

Variable		1	2	3	4	5	6	7	8
	N	20,713	20,713	18,074	9,267	9,267	9,267	9,267	9,267
1. PS enrollment immediately following graduation	11,124	—	-.10**	.20**	.14**	-.18**	-.11**	.20**	.01
2. Postsecondary first year persistence	11,124	-.05**	—	-.20**	.10**	.04**	.10**	-.11**	-.01
3. Postsecondary first year GPA	9,764	.14**	.08**	—	-.13**	-.15**	-.07**	.15**	.03**
4. Postsecondary time to degree	5,279	.14**	.12**	-.12**	—	-.33**	-.39**	.53**	.02*
5. Certificate or diploma < 2 years	5,279	-.15**	-.08**	-.18**	-.43**	—	-.12**	-.46**	.04**
6. Associate degree or 2-3-year diploma	5,279	-.09**	.05**	.02	-.28**	-.23**	—	-.82**	-.09**
7. Bachelor degree or higher	5,279	.18**	.01	.10**	.55**	-.48**	-.74**	—	.06**
8. Postsecondary STEM or MT degree field	5,279	-.03	-.03*	.02	-.04**	.10**	-.05**	-.03	—

Note: $^{*}p < .05$, $^{**}p < .01$. Statistics for math ACT scores < 22 and math ACT scores ≥ 22 are reported in the bottom left and top left of the table respectively. Postsecondary first year GPA and time to degree are continuous outcome variables. All other outcomes are binary variables dummy.

Table 8

Descriptive Statistics and Correlations Postsecondary Outcomes for Dual Credit College Algebra Takers After Matching

Variable	*N*	1	2	3	4	5	6	7	8
	N	9,862	9,862	6,950	3,349	3,349	3,349	3,349	3,349
1. PS enrollment immediately following graduation	4,360	—	-.20**	.11**	.15**	-.14**	-.10**	.18**	.01
2. Postsecondary first year persistence	4,360	-.11**	—	-.23**	.09**	.02	.10**	-.10**	-.01
3. Postsecondary first year GPA	3,482	.18**	-.03*	—	-.07**	-.16**	-.08**	.16**	.01
4. Postsecondary time to degree	1,630	.12**	.11**	-.11**	—	-.46**	-.35**	.60**	-.02
5. Certificate or diploma < 2 years	1,630	-.06*	-.04	-.17**	-.46**	—	-.15**	-.52**	.05**
6. Associate degree or 2-3-year diploma	1,630	-.11**	.06*	.02	-.30**	-.21**	—	-.77**	-.07**
7. Bachelor degree or higher	1,630	.14**	-.03	.08**	.58**	-.47**	-.77**	—	.03
8. Postsecondary STEM or MT degree field	1,630	-.02	.02	.03	-.06*	.14**	-.03	-.06*	—

Note: $^{*}p < .05$, $^{**}p < .01$. Statistics for math ACT scores < 22 and math ACT scores ≥ 22 are reported in the bottom left and top left of the table respectively. Postsecondary first year GPA and time to degree are continuous outcome variables. All other outcomes are binary variables dummy.

Table 9

Effects of Dual Credit College Algebra on Postsecondary Outcomes

	Jr Math ACT Subscore < 22				
	df	*F*	η^2	*B*	*SE*
PS enrollment immediately following graduation	8,698	48.60	0.06	0.05***	0.34
Postsecondary first year persistence	8,702	31.43	0.04	-0.06***	0.44
Postsecondary first year GPA	6,940	217.55	0.26	0.09***	0.84
Postsecondary time to degree	3,296	286.60	0.49	-0.16***	1.23
Certificate or diploma < 2 years	3,296	39.84	0.12	-0.02*	0.30
Associate degree or 2-3-year diploma	3,296	17.07	0.05	-0.01	0.43
Bachelor degree or higher	3,296	326.4	0.52	0.03***	0.42
Postsecondary STEM or MT degree field	3,296	13.90	0.04	-0.06***	0.43
	Jr Math ACT Subscore ≥ 22				
	df	*F*	η^2	*B*	*SE*
PS enrollment immediately following graduation	19,704	74.20	0.04	0.02***	0.26
Postsecondary first year persistence	19,704	163.58	0.08	-0.09***	0.47
Postsecondary first year GPA	1,3876	487.19	0.28	0.02	0.72
Postsecondary time to degree	6,754	488.74	0.44	-0.24***	0.90
Certificate or diploma < 2 years	6,754	67.45	0.10	0.02***	0.23
Associate degree or 2-3-year diploma	6,754	63.35	0.09	0.00	0.36
Bachelor degree or higher	6,754	736.82	0.55	-0.03***	0.35
Postsecondary STEM or MT degree field	6,754	28.73	0.04	-0.06***	0.45

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. Analysis results with control of student demographic characteristics of academic year, gender, race and ethnicity, student free/reduced lunch eligible, school free/reduced lunch eligible, census size, high school GPA, junior ACT English score, and junior ACT math score.

Results on Research Question 1

Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school increase the likelihood of enrollment in both two-year and four-year postsecondary education immediately following graduation?

Postsecondary enrollment immediately following graduation results for the < 22 math ACT group were significant ($p < .01$) with a medium effect size (see Table 9). College algebra takers would have a 5% higher rate of PS enrollment immediately following graduation, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .06$). Postsecondary enrollment immediately following graduation results for the ≥ 22 math ACT group were significant ($p < .01$) with a small effect size. College algebra takers would have a 2% higher rate of PS enrollment immediately following graduation, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .04$).

Results on Research Question 2

Research Question 2a. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school affect postsecondary first year persistence?

Postsecondary first-year persistence results for the < 22 math ACT group were significant ($p < .01$) with a small effect size (see Table 9). College algebra takers would have a 6% lower rate of first-year persistence, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .04$). Postsecondary first-year persistence results for the ≥ 22 math ACT group were significant ($p < .01$) with a medium effect size. College algebra takers would have a 9% lower rate of first-year persistence, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .08$).

Research Question 2b. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school affect postsecondary first year GPA?

Postsecondary first-year GPA results for the < 22 math ACT group were significant ($p < .01$) with a large effect size (see Table 9). College algebra takers would have a 0.09 point higher postsecondary first-year GPA, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .26$). Postsecondary first-year GPA results for the ≥ 22 math ACT group were not significant.

Research Question 2c. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school affect postsecondary time to degree and degree completion?

Postsecondary time to degree results for the < 22 math ACT group were significant ($p < .01$) with a large effect size (see Table 9). College algebra takers would have completed a certificate, associate degree or bachelor’s degree in .16 fewer years, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .49$). Postsecondary time to degree results for the ≥ 22 math ACT group were significant ($p < .01$) with a large effect size. College algebra takers would have completed a certificate, associate degree or bachelor's degree in .24 fewer years, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .44$).

Certificate or diploma < 2 years results for the < 22 math ACT group were significant ($p < .05$) with a medium effect size. College algebra takers would have a 2% lower rate of certificate attainment, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .12$). Certificate or diploma < 2 years results for the ≥ 22 math ACT group were significant ($p < .01$) with a medium effect size. College algebra takers would have a 2% higher rate of certificate attainment, controlling for student and school demographic characteristics, high school GPA, junior ACT English score and junior ACT math score ($\eta^2 = .10$).

Associate degree or 2-3-year diploma results for the < 22 math ACT group were not significant. Associate degree or 2-3-year diploma results for the ≥ 22 math ACT group were also not significant.

Bachelor degree or higher results for the < 22 math ACT group were significant ($p < .01$) with a large effect size. College algebra takers would have a 3% higher rate of completing a bachelor's degree or higher, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .52$). Bachelor degree or higher results for the ≥ 22 math ACT group were significant ($p < .01$) with a large effect size. College algebra takers would have a 3% lower rate of completing a bachelor's degree or higher, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .55$).

Research Question 2d. Controlling for student demographic characteristics, high school GPA, junior ACT English score, junior ACT math score, and high school demographics, does enrollment in a dual credit college algebra course during high school affect postsecondary degree attainment in a STEM or math/technology competency-based field?

Postsecondary STEM or MT degree field results for the < 22 math ACT group were significant ($p < .01$) with a small effect size (see Table 9). College algebra takers would have a 6% lower rate of completing a STEM or MT degree, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .04$). Postsecondary STEM or MT degree field results for the ≥ 22 math ACT group were significant ($p < .01$) with a small effect size. College algebra takers would also have a 6% lower rate of completing a STEM or MT degree, controlling for student and school demographic characteristics, high school GPA, junior ACT English score, and junior ACT math score ($\eta^2 = .04$).

Summary

This study had multiple stages. The first stage was to collect and compile demographic, academic, and postsecondary outcome data from KYSTATS. The next step was to clean the data, remove students with missing covariate information, and split the data into four groups based on treatment, non-treatment, and ACT math scores. The data were then compiled into postsecondary outcome groups consisting of those students who had available data for a given outcome. Once the data were cleaned and separated into postsecondary outcome groups, the next step was to match students in each ACT group who took dual credit college algebra to those who did not take college algebra using propensity score matching. Propensity score matching provided a data set with an equal number of treated and untreated students who shared similar demographics and academic achievement characteristics, reducing the variability between groups. Propensity score matching also provided a quasi-experimental control group which allowed for plausible causation. A linear regression analysis was completed comparing the postsecondary outcomes between dual credit college takers with < 22 or ≥ 22 math ACT and non-college algebra takers with < 22 or ≥ 22 math ACT. Results of the analysis indicated that there were statistically significant differences in postsecondary enrollment, persistence, time to degree and certificate and bachelor degree attainment. Postsecondary GPA was also found to be statistically significant for the < 22 math ACT group. Associate degree attainment was not found to be significant for either group.

Chapter 5: DISCUSSION

This quantitative study examined the effect of dual credit college algebra on postsecondary outcomes. The purpose of this chapter is to present a summary of the study findings, examine the findings in the context of current research literature, and discuss the implications of this study on educational policy and practice. The chapter concludes with limitations and recommendations for further research.

Specifically, the focus of this research was to examine the effect of dual credit college algebra participation on the following postsecondary outcomes: enrollment, persistence, GPA, and degree attainment. Of particular interest was the effect dual credit college algebra had on (mathematically) underprepared high school students with lower ACT scores. These students, for the most part, were not allowed to enroll in a credit-bearing college algebra course either as a dual credit student or as a degree seeking undergraduate.

Using student data collected from KYSTATS, this study attempted to determine if dual credit college algebra taking patterns impacted student postsecondary outcomes. Students were divided into two groups based on junior math ACT subscores, and each group was analyzed independently to study the effect of dual credit college algebra enrollment on both academically prepared and underprepared students. Due to the lack of a randomized control group, this study utilized propensity score matching to increase plausible causality. A linear regression was conducted on the matched pairs to examine the relationship between participation in dual credit college algebra and postsecondary enrollment, persistence, GPA, and degree outcomes.

Summary of Findings

The results of this study were statistically significant for a majority of the postsecondary outcomes for both math ACT groups. For students with junior ACT math scores < 22 (low ACT group), dual credit course taking was found to be statistically significant ($p < .001$) for six of eight postsecondary outcomes (see Table 9) and statistically significant ($p < .05$) for seven of eight postsecondary outcomes. Most findings had a medium to strong effect size (η^2), ranging from 0.04 for postsecondary STEM or MT degree field and postsecondary first year persistence to 0.52 for bachelor degree completion. The largest improvements in postsecondary outcomes, with a corresponding effect size ≥ 26, were postsecondary first year GPA, postsecondary time to degree, and bachelor degree completion. For students in the ≥ 22 math ACT (high ACT group), the effect of dual credit course taking was statistically significant ($p < .001$) for six of eight postsecondary outcomes. First year GPA and associate degree completion were both not statistically significant. Most findings had a medium to strong effect size (η^2) ranging from 0.04 for postsecondary STEM or MT degree field and postsecondary enrollment immediately following graduation, to 0.55 for bachelor degree completion. The largest improvement in postsecondary outcomes, with a corresponding large effect size of .44, was postsecondary time to degree.

Both groups had significantly positive results and comparable effect sizes for postsecondary enrollment immediately after high school. There was a 5% higher enrollment rate for dual credit college algebra (DCCA) students in the low ACT group and a 2% higher enrollment rate for DCCA students in the high ACT group. Postsecondary time to degree was also significant for both groups: low ACT DCCA students completed a degree 0.16 years before their non-DCCA peers, and high ACT DCCA students completed a degree 0.24 years before non-DCCA students. An interesting similarity for both groups was the significantly negative association with first year persistence. Results of the analysis showed DCCA students in the high ACT group were 6% less likely to persist through their first year of postsecondary education compared to 9% less likely for DCCA students in the low ACT group. First year. DCCA students in both ACT groups were reported as at least 6% less likely to complete a postsecondary STEM or MT degree.

Noteworthy contrasts in outcomes between the two ACT groups were seen in the results for first year GPA, certificate, and bachelor degree completion. While low ACT DCCA students had a significant first year GPA effect that was 0.09 points higher than non-DCCA students, there was no significant association in first year GPA between DCCA students and non-DCCA students in the high ACT group. Certificate and bachelor degree completion also had opposite effects for each math ACT group. Certificate completion was significantly negative at 2% for DCCA students in the low ACT group and significantly positive at 2% for DCCA students in the high ACT group. In contrast, bachelor degree completion was statistically significant for both groups, with the highest effect size, but reversed results. DCCA students from the low ACT group had a 3% higher rate of bachelor degree or higher attainment, and DCCA students from the high ACT group had a 3% lower rate of bachelor degree attainment than their non-DCCA peers.

Revisiting the Research Literature

There is a considerable body of research exploring the relationship between high school math course taking intensity and postsecondary outcomes. Additional research explores the relationship between dual credit course taking and postsecondary outcomes such as college enrollment, persistence, GPA, and bachelor degree attainment. However, little research exists that examines the impact of dual credit math course taking on middle- and low-achieving students (Karp et al., 2004). Because mathematics is one of the few fields that have strict pre-requisite requirements for enrollment in college algebra and higher-level math courses, dual credit mathematics courses are usually limited to higher achieving students. Research reporting the relationship between enrollment in dual credit math courses and postsecondary outcomes is limited and primarily involves high achieving students. This researcher was unable to find any studies that specifically explored the effect of dual credit college algebra on postsecondary outcomes for underprepared students.

Overall, the results of this study for DCCA students in the < 22 math ACT support previous research results in all areas but first year persistence. The results for DCCA students with ≥ 22 math ACT are less consistent, and comparable with postsecondary enrollment immediately following graduation and time to degree results of previous research. Several studies have been done reporting the positive effects of secondary academic course intensity and dual credit course work on postsecondary outcomes (Adelman, 2004, 2006; Bailey, Hughes and Karp, 2002; Kim and Bragg, 2008; Speroni, 2011). The current study provides new evidence of the relationship between dual credit college algebra enrollment and postsecondary outcomes for underprepared students in contrast to previous studies which primarily involved higher achieving students (Karp et al., 2004). It is worth noting that DCCA students in the < 22 math ACT group had very similar results to those reported in previous studies which examined the postsecondary effects of dual credit course taking. In contrast, the results for DCCA students in the ≥ 22 math ACT group were less consistent with previous research findings.

Postsecondary enrollment immediately following high school graduation. Dual credit college algebra students from both math ACT groups reported a significant and positive increase in the rate of postsecondary enrollment immediately after graduation, which was consistent with previous research associating academically intense math course taking in high school with higher rates of postsecondary enrollment (Adelman, 2006; Nobles, 2007; Oakes & Saunders, 2007). The results were also consistent with research findings suggesting a positive effect between dual credit course taking and postsecondary student enrollment (Bailey, Hughes and Karp, 2002; Kim and Bragg, 2008; Struhl and Vargas, 2012; Swanson, 2008). On average, holding ACT scores, gender, income, race and ethnicity constant, concurrently enrolled students have a higher likelihood of enrolling in college immediately after high school graduation (Bautsch, 2014; Giani, Alexander & Reyes, 2014).

First year persistence. The results of this study showed a statistically significant negative association between DCCA takers and first year persistence. In general, research reporting first year persistence rates showed a positive association between dual credit course taking and first year persistence. However, because of the broad variation found in defining postsecondary persistence, comparisons between the results of this study and previous research were inconclusive. In this study, first year persistence was defined as the accumulation of 12 credit hours during both the fall and spring semesters of the first undergraduate year (total first year accumulation = 24 credit hours). Other studies defined first year persistence in a variety of ways (e.g., returning to college at the beginning of the second undergraduate year, completion of 20 or more credit hours by the end of the first year, or persistence to a degree over the course of several semesters). Previous research reported students who took academically intense math courses in high school had higher rates of degree persistence than similar students who pursued fewer challenging courses (Adelman, 2006; Nobles, 2007; Oakes & Saunders, 2007).

Since a majority of the student data was collected during the 2009 – 2014 Great Recession it is reasonable to question whether many of the DCCA students who could afford dual credit courses were unable to afford the high cost of full-time postsecondary tuition (Ball, 2014). In such a case, measuring persistence as first-year full-time undergraduate enrollment would fail to capture students who enrolled in less than 24 credit hours during their freshman year, but persisted through to the second year and ultimately to a degree. A more accurate measurement of first-year persistence would perhaps have been to lower the number of completed first-year credit hours to 9 per semester (18 total credit hours the first year) or define persisting through the first year as returning to college at the beginning of the second undergraduate year.

First year GPA. The results of this study for both math ACT groups, although different, were consistent with previous research. The DCCA students in the < 22 math ACT group had a significantly larger first year GPA than their non-DCCA matched peers. Previous research results found high school course intensity and dual credit participation had a significant and positive association with postsecondary first year GPA (Adelman, 1999; Allen & Dadgar, 2012; An, 2015). Young, Joyner, and Slate (2013) found both White and African American dual credit students had a significantly higher first-term postsecondary GPA than White non-dual credit students. In contrast, first year GPA results for DCCA students in the high ACT math group were not significant. Similar results were reported by Berger, Turk-Bicakci, Garet, Knudson & Hoshen, (2014) who compared postsecondary GPAs between dual credit students and those in a comparison group and found postsecondary first year GPA was not significant (What Works Clearinghouse, 2017).

Time to degree. The results of this study comparing dual credit math taking and time to degree were significant and positive with large effect sizes for both math ACT groups, which were similar to previous study results. Research by Allen and Dadgar (2012) found dual credit students not only began their postsecondary education with more credit hours, but also took more hours in college reducing their time to degree. Similar results were reported by Swanson (2008) who found dual credit students missing no more than one semester from initial enrollment to the end of their sophomore year earned a degree in less than average time.

Certificate and associate degree completion. Previous research results associating dual credit course taking and certificate or associate degree completion were generally reported as part of the results for “likely to earn any degree” which would have included bachelor degree completion. Dual credit students were found to be significantly more likely to earn a postsecondary credential than non-dual credit students (Giani, Alexander, & Reyes, 2014; An, 2013; Blankenberger, Lichtenberger, & Witt, 2017). These results are somewhat consistent with those of this study for both math ACT groups.

Bachelor degree completion. In comparison, there is a wealth of research reporting a significant positive association between bachelor degree attainment and high school course taking intensity and dual credit enrollment. Results for students in the < 22 math ACT groups were consistent with the research, showing a significant and positive association (with a large effect size) for DCCA student bachelor degree completion compared to non-DCCA students. Several studies found academic intensity of the high school curriculum was one of the most important pre-collegiate factors influencing bachelor's degree completion (Adelman, 1999; Attewell, Lavin, Domina, & Levey, 2006; Park et al, 2018). Adelman (2006) found increasing the intensity of the high school curriculum had the highest impact on postsecondary success, and math curriculum intensity exhibited the strongest correlation with bachelor’s degree attainment, followed by class rank/GPA and test scores. Dual credit course taking was shown to have a positive impact on postsecondary student enrollment and degree attainment. Underprepared students who completed dual credit courses were more likely to graduate from high school, enroll in a four-year postsecondary institution, and persist to a degree in college. They were also less likely to be placed into developmental education courses (Allen & Dadgar, 2012; An, 2013; Bailey, et al, 2002; Blankenberger, et al, 2017; Giani et al., 2014; Kim and Bragg, 2008; Hughes, Rodriguez, Edwards & Belfield 2012; Struhl and Vargas, 2012). Kim and Bragg (2008) found enrollment in dual credit math courses based on hours earned positively correlated with college readiness and postsecondary degree attainment.

In contrast, students in the ≥ 22 math ACT group showed a negative association with bachelor degree completion. This was not consistent with research findings comparing bachelor degree attainment to math curriculum intensity or dual credit course taking. In fact, the results were significantly negative with a large effect size. The cause for this unique result is currently unknown but does add complexity to the research literature and is a cause for concern. One of the unique aspects of this research was the homogeneous composition of the < 22 math ACT group where a majority of the DCCA students were enrolled in the A2A dual credit college algebra course. In contrast students in the ≥ 22 math ACT group were enrolled in a wide variety of dual credit college algebra programs from public and private postsecondary institutions across the state of Kentucky. Although the college algebra content is generally the same, the method of delivery, expectations, student engagement, teacher qualifications, training and professional development are determined by the individual postsecondary institution and can play a significant role in both student success and postsecondary preparation (Roher, 2007; Thiel, Peterman, & Brown, 2008). Analyzing bachelor degree attainment for students in the ≥ 22 math ACT group, while controlling for dual credit college algebra program could perhaps better inform the results of the analysis.

STEM or MT degree attainment. The researcher was unable to find any studies examining the relationship between dual credit college algebra taking and STEM or MT degree attainment. The results of this study indicate that dual credit college algebra taking did not increase STEM and MT degree attainment and in fact DCCA students were significantly less likely to compete a STEM or MT degree. Previous research found that intent to major in a STEM field was correlated to both 10th and 12th grade math achievement and math self-efficacy (Wang, 2013). Perhaps students who intended to major in a STEM or MT field were more likely to be enrolled in more advanced math courses such as AP calculus. Further study in this area is needed.

Implications for Educational Policy and Practice

With comprehensive state data and a credible simulation to an experimental design, the overall position of this study supports the dual credit approach particularly for mathematically underprepared high school students. This study aims to contribute to the national discussion concerning dual credit course taking. Over the last decade, dual credit has been widely implemented but, for the most part, remains limited to higher achieving students. There is a limited amount of research measuring the effect of dual credit math course taking on middle- and low-achieving students (Karp et al., 2004). The researcher for this study was unable to find any previous research comparing the effects of dual credit college algebra on postsecondary outcomes for low-achieving students. There is limited research which explores the results of dual credit course taking on postsecondary gains for middle-prepared students which includes dual credit college algebra. The results of this study were very similar to a study done by Speroni (2011), who found that students who were marginally eligible for dual credit college algebra did not show improved rates of college enrollment or degree attainment after taking general dual credit courses. However, marginally eligible students taking dual credit college algebra experienced large and significant effects on college enrollment and degree attainment. She posits that students who experience a rigorous curriculum while still in high school might be better academically prepared for college and possibly “students who have already taken college-level algebra start college with higher self-esteem and confidence in their ability to obtain a degree” (Speroni, 2011, p. 47)

Dual credit is an increasingly popular and effective academic mechanism intended to improve student postsecondary outcomes (Karp, 2006). As mentioned in chapter 2, equal access to dual credit coursework continues to be a challenge, as many states and postsecondary institutions consider content assimilation the primary measure of preparation for dual credit coursework, using ACT/SAT benchmarks, high stakes placement testing, and college-level academic requirements for dual credit participation (An, 2013; Karp, Bailey, Hughes, & Fermin, 2004). Although opponents believe that increased access to dual credit coursework will either reduce student motivation to succeed in high school or reduce the quality, rigor, and college-level standards of dual credit courses (Baily, Hughes and Karp, 2003), the results of this study argue against that assumption. This study’s results, combined with the strong relationship between high school course taking intensity and postsecondary success particularly in the area of mathematics (Adelman, 1999), provides another strong argument for opening access to dual credit mathematics for middle- and low-achieving high school students (Baily, Hughes, & Karp, 2003).

Underprepared students continue to be placed into developmental courses at the community college level. Approximately one in five students who take developmental math eventually pass a GE math course, and less than 30% continue on to graduate and attain a degree in less than 8 years (Bailey, Jeong, & Cho, 2010; Jaggars & Stacey, 2014). Because minority students make up a disproportionate number of those enrolled in developmental courses, access to dual credit mathematics coursework touches heavily upon the issue of equity (Riehl, Henig, Wolff & Rebell, 2019; Venizia & Jaeger, 2013). Providing equitable access to dual credit math coursework based on qualifiers other than high stakes placement tests and math ACT benchmarks would be a significant step in addressing the inequities in high school preparation and postsecondary degree attainment for SES and minority students (Riehl, Henig, Wolff & Rebell, 2019).

By its very nature, dual credit courses bridge the institutional gap between postsecondary and secondary by requiring interaction between institutions, which in turn directly and indirectly influence both academic and nonacademic proficiency (Karp, 2013). In 2001, the National Commission on the High School Senior Year reported that only ten states had aligned their high school graduation and college admissions requirements in English and only two had aligned their requirements in math in spite of the fact that each year a substantial number of high school seniors graduate underprepared for college level mathematics. The results of this study demonstrated postsecondary gains for students taking dual credit college algebra even without final course grades included as a control factor due to missing data. Even with the inclusion of DCCA students who would not have passed the course with a C or better, the results for the < 22 math ACT group reported significant gains in postsecondary outcomes. Is it possible that allowing students to be exposed to college level math coursework prepares them for the rigor and expectations of postsecondary education regardless of grade outcome?

When middle- and low-achieving students are not allowed to attempt college level math coursework, they are excluded from experiencing the expectations and non-cognitive lessons needed for postsecondary success. More high school students need to have the opportunity to experience the rigor, pacing and expectations of postsecondary courses while still in high school and with the additional supports high schools can provide. According to What Works Clearinghouse (2017), when postsecondary course experience is combined with consistent professional development and training for secondary dual credit college algebra teachers, a student's need for developmental coursework would be reduced, and the probability of college degree attainment increase. Because dual credit courses are tremendously discounted or free, increasing access to these courses could potentially improve postsecondary enrollment and bachelor degree attainment for low SES students who make up a large number of underprepared high school graduates.

If increased access to dual credit course work is not accompanied by a corresponding increase in postsecondary undergraduate financial support, differences in student/family income levels will remain a barrier to postsecondary degree attainment. As quoted earlier by Arne Duncan, education is one of the surest ways out of poverty. Although many states have done much to make dual credit affordable, the cost of a postsecondary education continues to increase dramatically. Postsecondary institutions should be prepared to support and provide financial assistance to students who successfully complete dual credit coursework and are prepared to enroll in a postsecondary institution. Otherwise students from lower income levels who successfully complete dual credit course work might find themselves unable to complete or even begin a postsecondary degree. It is critical that postsecondary institutions and state legislators find a way to make postsecondary education more affordable for students from lower income backgrounds.

Research Limitations

There are always limitations inherent in conducting educational research. In this study, lack of standardization on data collection was a limitation. When data collection is not internally consistent (i.e., without a pre-established standard procedure for each and every data collection to follow through), it is very possible to increase errors among collected data. This study also lacked a rigorous control group. The recruitment for the A2A dual credit college algebra program participants was voluntary and through word of mouth. Students at a given school who were interested in participating (provided they had a C or higher in Algebra II with counselor/teacher approval) were allowed to participate in the A2A program. Enrollment in other statewide dual credit college algebra programs was also voluntary as long as students met the prerequisite ACT/SAT and placement exam benchmarks. In reality, it was simply impossible to find a control group of students with similar demographic and academic backgrounds but with restricted access to the A2A program. Technically, there was no control group in this study. To overcome this lack, PSM was used as a credible simulation to an experimental design when a researcher is unable to conduct a "pure" experiment with random selection. This study used PSM (which relies on the assumption of unconfoundedness) to create a control group. Even so, the study did not control for individual student differences beyond the variables included as matching covariates.

Another limitation of this study was the lack of school characteristics. Although the state data had some school characteristics (e.g., demographic characteristics of students, staff and faculty, staff and faculty degree levels, and faculty credentials), only simple school information was used as matching information in this study. This limitation was partly related to the final limitation. Because the data at hand were hierarchical in nature with students nested within schools, any PSM effort should take into account information at both levels. Even though there was limited information on school characteristics (e.g., school location), this study treated that information as if it were student-level information (i.e., each student had a code for school location). At this stage, the multilevel PSM model is still in its infancy. Nonetheless, the inability of this study to conduct PSM simultaneously at both student and school levels compromised the results to a certain degree.

The inability to examine the postsecondary outcomes for students who attended private and out-of-state postsecondary institutions was another limitation. KYSTATS collects data from public postsecondary institutions only. Private postsecondary institutions can voluntarily supply detailed data but are not compelled to do so. Missing postsecondary data for students attending private or out-of-state postsecondary institutions caused a substantial reduction in the sample size of the treatment group.

Future Research

Further research needs to be done examining the association between dual credit college algebra course taking and postsecondary outcomes using experimental methods whenever possible. Only randomized experiments can inform changes in policy at the state and institutional levels. A substantial amount of time needs to be allocated for understanding, aggregating, and screening large institutional data sets, such as the one used in this study, in addition to collecting private and out-of-state postsecondary data from governmental agencies. It is the experience of this study that, even though state data is rich and comprehensive, it requires time to clean and be made ready for analysis. Many data issues are extremely complex and time-consuming to handle. Of course, there is always the reality that it is impossible to perform true experiments, and the only option is to utilize existing state data. This study is such a case. In situations like this, pursuing multilevel propensity score matching, simultaneously matching both students and schools, would become increasingly necessary. Methodological advancement is needed to make multiple PSM operational for even novice researchers with a limited statistical background.

Finally, exploring the relationship between qualitative characteristics (e.g., motivation, academic confidence, growth mindset, and self-efficacy) of underprepared students taking dual credit courses could supply both secondary and postsecondary institutions with critical insights into educational practices that would help align the two institutional levels and better prepare all students for postsecondary success.

Conclusions

This study was designed to investigate the impact of dual credit college algebra on postsecondary outcomes. Although the size of the < 22 math ACT treatment group was fairly small, the large data set of untreated subjects allowed for propensity scores to be matched using the strictest caliper with only a small reduction in sample size (< 10). Overall, the results were mostly significant and showed small to medium gains in postsecondary achievement between DCCA students and non-DCCA students. The results for students in the < 22 math ACT group were very informative since data on underprepared students enrolling in dual credit college algebra is very hard to find. It is clear that students in both ACT groups received postsecondary benefits from enrolling in dual credit college algebra, and the results for underprepared students in the < 22 ACT group warrant further investigation.

Appendix A

Descriptive Statistics of Sociodemographic Characteristics Prior to Matching

	No DC College Algebra (N = 174,801)		DC College Algebra Treatment (N = 13,967)	
	N	%	N	%
Senior Academic Year				
2009 – 2105	117,691	67.3	7,326	52.1
2016 - 2019	57,110	32.7	6,730	47.9
Gender				
Female	97,647	55.9	8,326	59.2
Male	77,154	44.1	5,641	40.1
Missing	0	0	89	0.6
Race/Ethnicity				
White	153,065	87.6	12,956	92.2
African American	17,372	9.9	770	5.5
Hispanic	1,797	1.0	72	0.5
Asian	2,567	1.5	169	1.2
Missing	0	0	89	0.6
Free/Reduced Lunch				
Paid	105,807	60.5	9,580	68.2
Reduced Lunch	9,697	5.5	733	5.2
Free	59,279	33.9	3,743	26.6
School Title 1 Status				
< 35% PVL	74,461	42.6	3,525	25.1
35% < PVL < 40%	63,795	36.5	7,009	49.9
> 40% PVL	36,545	20.9	3,522	25.1
School Census Size				
Rural	44,468	25.4	4,190	29.8
Micropolitan	38,064	21.8	3,563	25.3
Metropolitan	93,369	52.8	6,303	44.8

Note: PVL = Poverty Level

Appendix B

Descriptive Statistics of Academic Achievement Prior to Matching

	No DC College Algebra	College Algebra Treatment	No DC College Algebra	College Algebra Treatment
	M	*SD*	*M*	*SD*
Final High School GPA	3.17	0.58	3.53	0.41
Jr ACT English Subscore	20.43	5.67	23.70	4.74
Jr ACT Math Subscore	19.95	4.41	23.00	3.40

Appendix C

Results on Propensity Score Matching (PSM)

Once the screening of data was complete, propensity score matching was performed for each ACT math group in each dependent variable group. Students were matched based on the covariates, academic of year, gender, race and ethnicity, student free/reduced lunch eligible, school free/reduced lunch eligible, census size, high school GPA, junior ACT English score, and junior ACT Math score. PSM analysis was conducted using exact matching also known as nearest neighbor matching which is considered to be the best PSM technique (Ho, 2007). For this study each student was assigned an estimated propensity score and a strict caliper of 5% of the standard deviation was used for score matching. The propensity score for individual is denoted by

$$\boldsymbol{e_i = P(T_i = 1|X_i)}$$

where $\boldsymbol{e_i}$ is the estimated propensity score for subject $\boldsymbol{i}$, $\boldsymbol{T_i}$ is the treatment/non-treatment variable for subject $\boldsymbol{i}$ ($T = 1$ for treatment and $T = 0$ for control), $\boldsymbol{X}$ is the vector of covariates and $\boldsymbol{X_i}$ is the vector of covariate values for subject i.

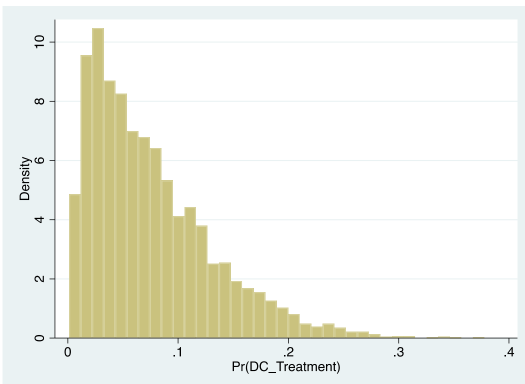
Propensity scores for students who did not take dual credit college algebra were compared to scores for students who took dual credit college algebra their senior year for students with < 22 math ACT and again for students with ≥ 22 math ACT. Students in each of the 4 groups with propensity scores within a range of .05 standard deviations were matched. The effects of matching caused a small reduction in sample size for each of the postsecondary outcomes (< 10 subjects). When matching was completed, the matched treated and untreated subjects in both ACT groups were analyzed for covariate balance between the treatment and untreated students based on standardized differences (effect size) and density plots (Austin, 2009, 2011).

Appendix D

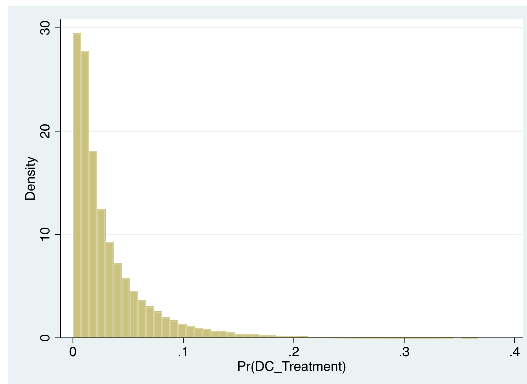
Figure 1. Histograms of Postsecondary Enrollment Immediately Following Graduation: After Matching

< 22 math ACT

Matched Treatment

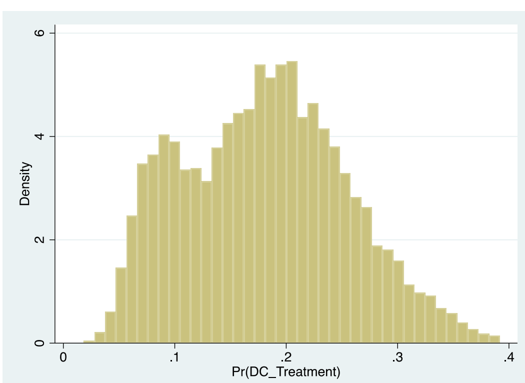


Matched Control



≥ 22 math ACT

Matched Treatment



Matched Control

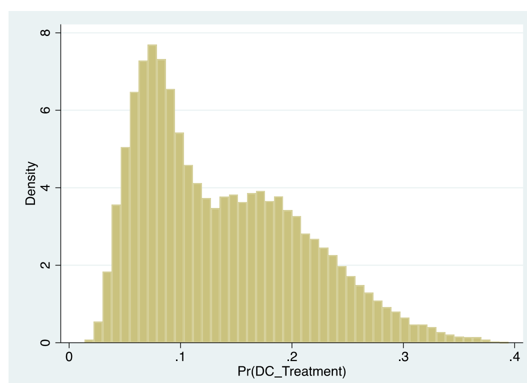


Figure 2. Histograms of Postsecondary First Year Persistence: After Matching

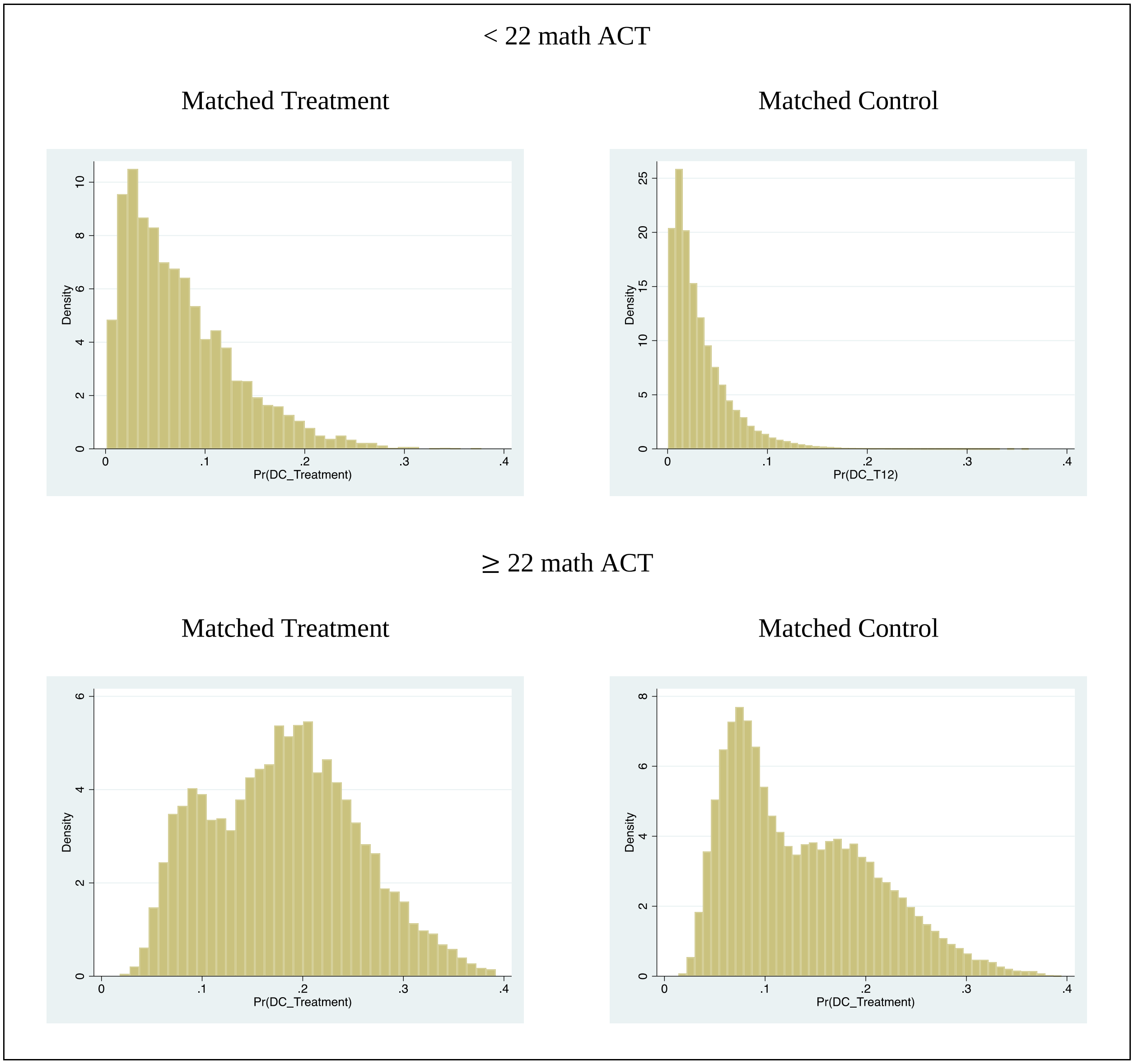


Figure 3. Histograms of Postsecondary First Year GPA: After Matching

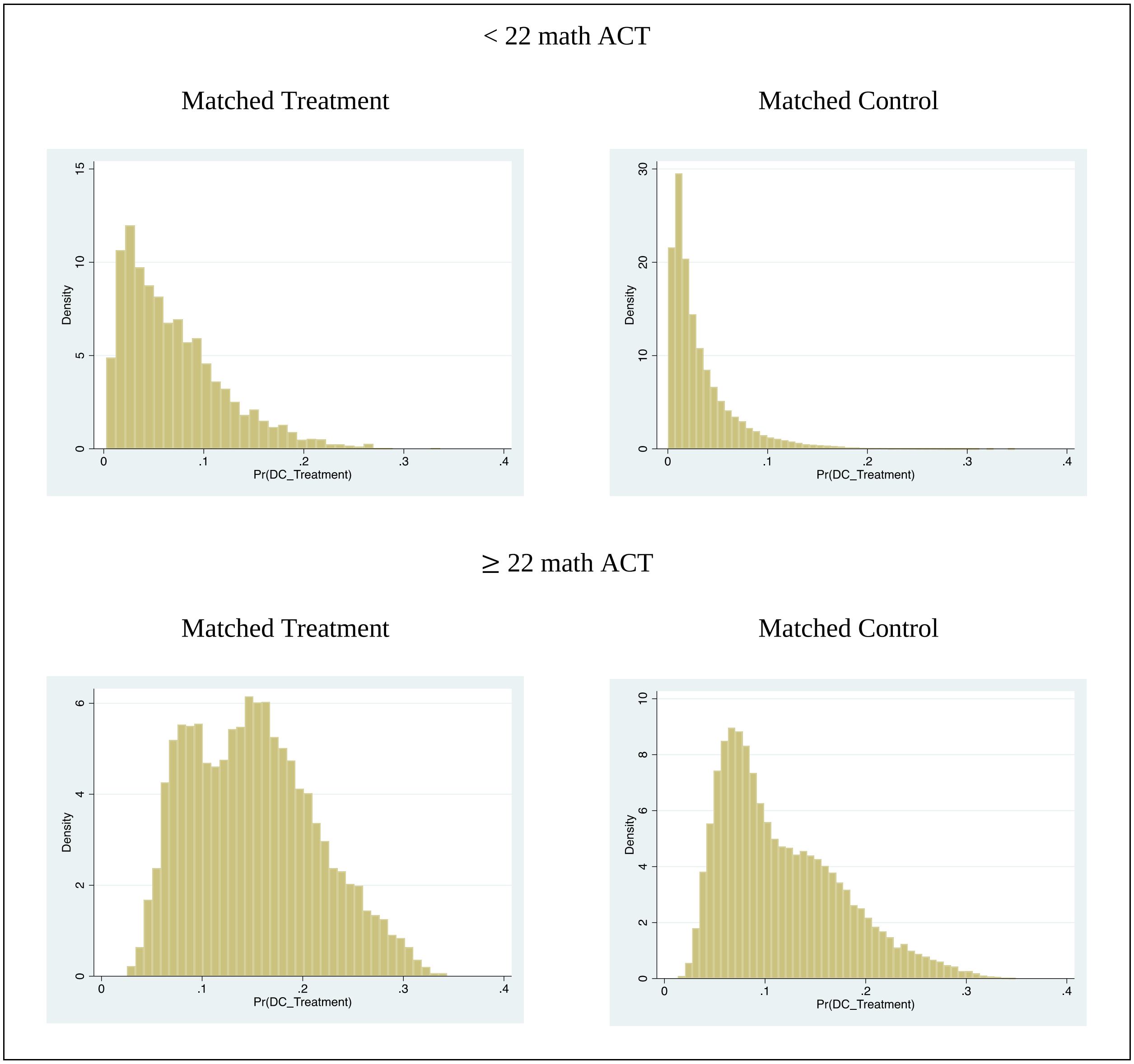
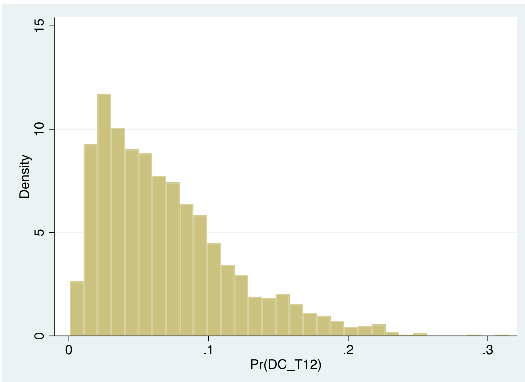


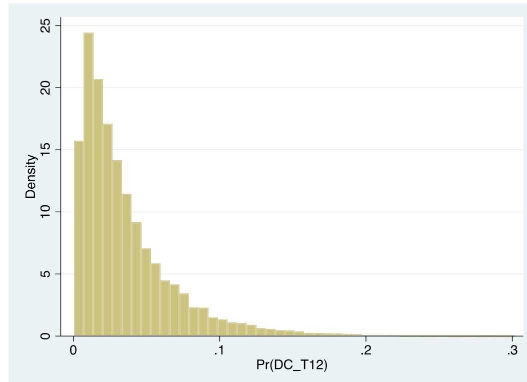
Figure 4. Histograms of Postsecondary Degree Outcomes: After Matching

< 22 math ACT

Matched Treatment

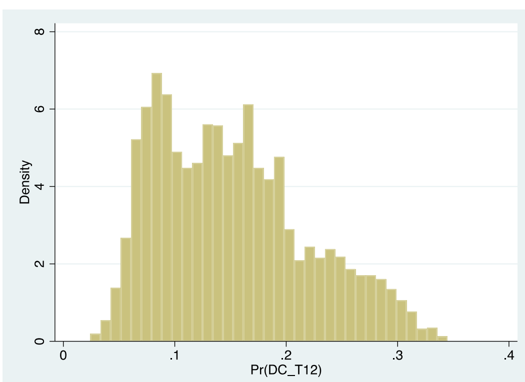


Matched Control

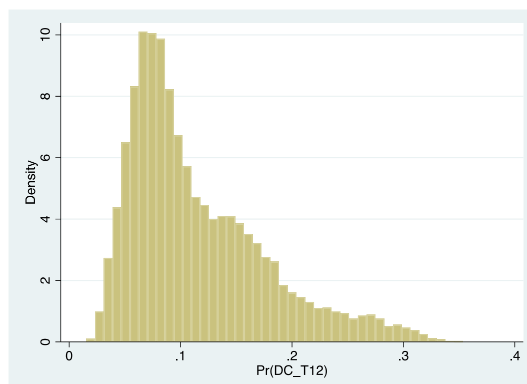


≥ 22 math ACT

Matched Treatment



Matched Control



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