Community College Science and Mathematics Coursetaking and Performance and Their Relationship to Graduation, Transfer, and Science Persistence

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Community colleges serve a unique role in higher education in the United States, providing universal access for students to learn the skills and knowledge that may promote their social and economic mobility. Students who have not had access to traditional four-year institutions historically have been able to pursue higher education at community colleges due to their open enrollments, affordable tuition, and geographic proximity. Community colleges serve a vital role in the education of science, technology, engineering, and mathematics (STEM) majors in the U.S., as nearly half of all students who have completed post-secondary degrees in these disciplines attended a community college. However, most research to date on STEM pipeline persistence from academia to the workforce has focused on four-year colleges, which limits understanding of the potential of two-year pathways in diversifying STEM participation.

In the present thesis, student persistence and academic outcomes in STEM were examined for over 1,500 community college students in New York State. Three years of transcript data were collected for each of three cohorts who matriculated between 2011 and 2014. Data analyzed included grades, demographics, degree change patterns, and graduation and transfer status.

In the first of three distinct yet related studies, descriptive statistics indicated that students who enrolled in science and mathematics coursework were more likely to graduate or transfer and completed more of their credits successfully than those who did not. Students who did not graduate or transfer earned lower GPAs and course completion rates in all academic areas. Binary logistic models revealed that for non-STEM majors, the rate of science and mathematics course completion, science and mathematics course enrollment, and required mathematics and English remediation coursework were significant predictors of graduation and transfer. In the
second study, 32% of students received grades of D, F, or W in introductory chemistry, with 49% changing their majors and 80% of those degree changers switching to non-STEM fields. Binary logistic regression models indicated that chemistry enrollment was a significant predictor of degree change to non-STEM disciplines while biology and anatomy/physiology coursetaking predicted STEM persistence. In the third study, students who first enrolled in developmental mathematics experienced a higher likelihood of changing to non-STEM majors, experienced greater attrition, lowered credit production rates, weaker science performance, and lowered graduation or transfer rates. Students who completed developmental mathematics courses failed algebra and trigonometry at a rate of 68%, and students who qualified for advanced mathematics as their entry level course outperformed students who initially enrolled in lower level mathematics courses. Demographic variables and socioeconomic status had limited predictive value for STEM-related outcomes.

These results indicated that chemistry coursetaking and performance were notable factors affecting student persistence in STEM disciplines, outcomes were largely independent of student background variables, and remediation coursework did not prepare most students for the mathematics required for STEM degrees. Community college policy makers may improve student outcomes by providing supports for science and mathematics coursework. STEM majors may benefit from reconceptualized developmental curricula focused on essential skills for success in advanced mathematics and science, as well as clarity on transferable coursework and structured pathways to reach the milestones required for STEM degrees and careers. Finally, a universal methodology for calculating transfer rates should be developed and combined with graduation rates in order to create a better assessment of the effectiveness of community colleges.
Dedication

This dissertation is dedicated to my wife Stacey. I would never have been able to complete it without your endless love, support, and (in her own words) “strategic nagging.”
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As first author, I was responsible for the majority of research design, data collection, analysis, and writing of the manuscripts. Permission was granted by Dr. Angela Kelly as co-author to include these works in the present dissertation.
Chapter 1

Introduction

1.1 Statement of the Problem

A community college is defined as any institution that is accredited to award the associate’s degree as its highest degree (Cohen, 2001). By facilitating the development of skills and knowledge that enhance social and economic mobility, community colleges have addressed a critical role in higher education in the U.S. (Rankin, Katsinas, & Hardy, 2010), while educating 45% of all college students (American Association of Community Colleges [AACC], 2016; National Center for Education Statistics [NCES], 2014). Of students enrolled in public four-year institutions in 2011-12, 35% had completed at least part of their academic coursework at community colleges (AACC, 2016). Through open enrollment and affordable tuition, community colleges provide the opportunity for many students to pursue higher education who would not otherwise be able to do so (Bailey, Jenkins, & Leinbach, 2005). Community colleges uniquely give access to higher education for minority populations, as 84% of new, first-time students are non-White and half of all students enrolled in community colleges are minorities (AACC, 2016). Community colleges also fill an important gap in the STEM pipeline as nearly half of all students who completed a bachelor’s, master’s, or doctoral degree in a STEM field between 2008-2013 attended a community college at some stage and the number of STEM-related associates degrees awarded between 2000-2015 increased 90,000 per year (an increase of 135%) (National Science Board, 2018).

This quantitative study employed a multi-faceted approach in exploring the role that community colleges have in STEM preparation by exploring how science and mathematics coursework impacted graduation, transfer, and persistence rates at a large suburban community college in New York State. The first study explored the relationship between science and mathematics course enrollment and completion, graduation, and transfer status of non-STEM liberal arts majors, and identified science and mathematics academic factors that best predicted graduation and transfer outcomes for these students. The second study explored how chemistry performance related to student variables and disciplinary persistence for STEM majors and how chemistry enrollment compared to biology, anatomy/physiology, and physics in predicting STEM degree persistence. The third study explored how student characteristics, mathematics placement, and mathematics performance of students related to the following academic variables: disciplinary persistence, graduation and/or transfer rates, enrollment attrition, science performance, and credit production rate. A summary of the research questions and sample population of each study is presented in Figure 1.
Figure 1. Summary of research questions.

1.2 Rationale for the Study

An understanding of the history of community colleges provides key insights into how their mission has evolved over time. Community colleges trace their origins back to the early 20th century as institutions designed to train workers for the country’s expanding industrialization (Cohen, Brawer, & Kisker, 2013). Over the past century, their role has evolved to fill a variety of missions as today’s community colleges offer not just certificate programs, basic education, remedial programs, and vocational training, but associate’s degrees that many students use to transfer to the most prestigious programs in the country (Milliron & Wilson, 2004). Although now viewed as an entry point to higher education for millions of students, community colleges did not start out that way. Early educational reformers, including Nicholas Murray Butler from Columbia, David Starr Jordan from Stanford, and William Rainey Harper from Chicago, believed that the first two years of college were an unnecessary part of university-level instruction which should be reserved for the elite; to accomplish that goal, Harper divided the University of Chicago into two halves, the Junior College and the Senior College, and developed an “associate’s degree” for those students who completed the Junior College portion (Brint & Karabel, 1989). Harper also actively solicited Chicago area high schools to extend their offerings to college level work; J. Stanley Brown, a personal friend of Harper and principal of Joilet High School, took him up on his offer and Joilet Junior College became the first public Junior College to open in 1901 (Witt, 1994). Lange and Jordan pushed the idea of Junior Colleges in California so their universities could focus on research and scholarship (Beach, 2010).

Perhaps no publication had a larger influence on the expansion of Junior Colleges than the six volume report, \textit{Higher Education for American Democracy}, which was issued by the Truman Commission (Tillery & Deegan, 1985). The impetus for this report was President Truman’s view that American higher education was too elitist (Witt, 1994). The report advocated for free education up to the 14th grade and proposed the creation of new two-year colleges nationwide in order to help achieve that goal (Cohen, 2001). The vision of these schools echoed Harper’s from...
decades prior as they were to be extensions of area high schools, as highlighted by the fact that the term Junior College was abandoned in favor of Community College. Although general education was a goal outlined in the report, it also called for these schools to offer a variety of terminal, semiprofessional, public service, and recreational programs based upon local needs (Beach, 2010). Another emphasis of the report was these schools were to be open to underserved minority students (Witt, 1994). The *Open Door Colleges* report issued by the Carnegie Commission on Higher Education followed and solidified the use of the term “community college” and supported their continued expansion, but concluded that only one-third of students ended up successfully transferring at the culmination of their degrees (Beach, 2010). Although noting that minority populations were largely underrepresented, the report favored restricting access to community colleges to high school graduates (or similarly qualified individuals), which would further limit access to underrepresented populations (Brint & Karabel, 1989).

From the very beginning of junior colleges, students sought access to universities as a means to improve their social and economic status (Brint & Karabel, 1989). Junior colleges were viewed as a pathway to earn liberal arts credits that would enable them to transfer into the universities since the early junior colleges focused on the liberal arts, with three-quarters of their offerings being in those fields in 1924 (Cohen et al., 2013). However, early leaders of the junior college movement considered the disinterest of the students for anything other than transfer credits as the biggest problem facing junior colleges. Most educators agreed that by 1940 between two-thirds and three-fourths of all community college students should be enrolled in terminal degrees (Cohen, 2011). The opposition of students to vocational programs continued until the 1970s when students finally became interested in vocational programs when the labor market for college graduates softened (Brint & Karabel, 1989).

There is a need to determine whether today’s community colleges are fulfilling their mission, to explore whether they are providing access to higher education for traditionally underserved communities and expanding the talent pool for STEM careers. This paper used Tinto’s academic integration model (1975, 1999, 2006), Seymour & Hewitt’s (1997) research into the role of gateway courses in attrition from STEM majors, Bahr’s (2013) “deconstructive” approach, and social cognitive theory as critical lenses by which to answer these questions.

### 1.3 Overview of the Thesis

This thesis presents the results of three different studies, each exploring a different aspect of STEM education. The first study examined the role undergraduate STEM coursework plays in graduation and transfer rates of community college students. Nearly half of all students at the institution studied were enrolled in the non-STEM liberal arts degree; the transcripts of these key stakeholders were a source of data for researching the relationship between STEM coursework and metrics associated with successful academic outcomes. The second and third studies focused on the impact that select science and mathematics gateway course enrollment and performance had on STEM degree completion. As policy documents have highlighted the importance of increasing rates of STEM degree completion and increasing diversity in STEM (National Academies of Sciences, Engineering, & Medicine [NAS], 2016; National Governors Association, 2011; National Research Council [NRC], 2011; Olson & Labov, 2012), these studies provided insights that can be used to create targeted interventions to achieve the desired outcomes. This study was approved by the Institutional Review Boards of Stony Brook University (#848488) and Nassau County Community College (#11262015).
Paper 1: The impact of community college science and mathematics coursetaking and remediation on graduation, transfer, and non-completion rates. Community colleges serve a unique role in higher education in the United States, providing universal access for students to learn the skills and knowledge that may promote their social and economic mobility. Science and mathematics course enrollment and completion have sometimes been viewed as impediments to student graduation and transfer, valued academic outcomes as students earn required credentials for continuing education and career pathways. There is a need to quantify student academic outcomes and their relationship to graduation and transfer to improve career and advanced higher education readiness for community college students. This study explored science, mathematics, and general academic factors that predicted outcomes for community college students in a regional institution. Tinto’s academic integration model (1975, 1999, 2006) was used as the lens by which to understand the impact of these factors and to suggest targeted interventions to improve outcomes. Transcript data were collected for three cohorts spanning three years each and included grades, demographics, enrollment patterns, completion status and transfer status for 3,052 students enrolled in the non-STEM Liberal Arts degree. Descriptive statistics indicated that students who enrolled in science and mathematics coursework were more likely to graduate or transfer and completed more of their credits successfully than those who did not. Students who did not graduate or transfer earned lower GPAs and course completion rates in all academic areas. A binary logistic regression revealed that the rate of science and mathematics course completion, science and mathematics course enrollment, and required mathematics and English remediation coursework were significant predictors of graduation and transfer. Results have implications for community college policy makers in strategizing to improve student outcomes by providing supports for specific academic coursework.

Paper 2: Community college chemistry coursetaking and STEM academic persistence. Community colleges educate nearly half of all students who complete post-secondary degrees in science, technology, engineering, and mathematics (STEM) disciplines. For many matriculated students, chemistry is a required gatekeeping course for post-secondary retention and advancement in STEM majors. Using Seymour and Hewitt’s (1997) seminal research on STEM attrition as a theoretical base, this research explored community college student enrollment and performance in introductory chemistry courses for STEM majors, and how chemistry achievement related to student background characteristics and degree persistence. Data included grades, demographics, enrollment patterns, and degree status for 1,690 chemistry students who matriculated at a diverse, suburban community college from 2011-14. Descriptive statistics indicated 32% of students received grades of D, F, or W in introductory chemistry; 49% of these students changed their majors after taking the course, with four-fifths of those degree changers switching to non-STEM fields. Binary logistic regression models revealed that chemistry enrollment was a significant predictor of degree change to non-STEM disciplines, with biology and anatomy/physiology coursetaking predicting STEM persistence. Degree change to non-STEM was predicted by chemistry performance but not by student characteristics including gender, ethnicity, and socioeconomic status. The results indicate that chemistry coursetaking and performance is a notable factor affecting student persistence in STEM disciplines, and achievement is largely independent of student background variables. Implications for community college chemistry teaching and STEM academic advisement are discussed.
Paper 3: Mathematics as a factor in community college science performance, persistence, and degree attainment. Community colleges serve a vital role in the education of STEM majors in the U.S., however, most research to date on STEM pipeline persistence from academia to the workforce has focused on four-year colleges, which limits understanding of the potential of two-year pathways in diversifying STEM participation. One chronic issue is the vertical alignment of community college STEM education with workforce demands and advancement to baccalaureate institutions. This research builds upon prior work by exploring the initial mathematics enrollment and performance of STEM majors, and how this relates to demographic and socioeconomic variables and the likelihood of degree change from STEM to non-STEM disciplines, graduation and transfer rates, attrition from college, science performance, and credit production. This explanatory observational study employed deconstructive analysis and multiple regression techniques to examine transcript data from four cohorts of community college STEM majors \((N=1511)\) over three years of enrollment in an institution in the Northeast U.S. Results indicated that students who first enrolled in remedial mathematics courses experienced a higher likelihood of changing to non-STEM majors, greater attrition, lower credit production, weaker science performance, and lower rates of graduation and transfer to four-year colleges. Students who completed developmental mathematics courses failed algebra and trigonometry at a rate of 68%, indicating remediation coursework did not prepare most students for the mathematics required for science degrees. Students who qualified for advanced mathematics as their entry level course outperformed students who first took lower level classes. Demographic variables and socioeconomic status had limited predictive value for STEM-related outcomes. Results suggest that community college STEM majors may benefit from reconceptualized developmental curricula focused on essential skills for success in advanced mathematics and science, as well as clarity on transferable coursework and structured pathways to reach the milestones required for STEM degrees and careers.

1.4 Implications for Community College STEM Education Policy and Practice

This study has several important implications for STEM education policy and practice. As opposed to rating community colleges on graduation rates alone, a universal methodology for determining transfer rates should be developed and used in conjunction with graduation rates to better reflect the effectiveness of community colleges. The models developed in this study indicated that academic variables were significant predictors of student outcomes, while demographic variables had limited predictive value, suggesting that community colleges can increase diversity in STEM by focusing on academic-related interventions. Non-STEM majors were found to be taking science and mathematics courses designed for STEM majors which may have contributed to non-completion rates, therefore, increasing the availability of trained advisors with knowledge of appropriate science and mathematics coursework for the student’s major may increase retention and completion rates. Explicit and comprehensive institutional communication may help guide students along degree pathways, resulting in improved academic outcomes. The expansion of bridge programs geared towards students with deficiencies in mathematics and chemistry may improve outcomes as both courses were shown to be important predictors of retention in STEM. Community colleges should also consider reconceptualizing how to prepare students for advanced mathematics, as developmental mathematics and algebra and trigonometry were both shown to be generally ineffective in doing so.
Chapter 2

The Impact of Community College Science and Mathematics Coursetaking and Remediation on Graduation, Transfer, and Non-Completion Rates

2.1 Introduction

Community colleges serve a unique role in higher education in the United States, providing universal access for students to learn the skills and knowledge that may promote their social and economic mobility (Rankin et al., 2010). Recent policy documents have also highlighted the value of community colleges in providing entry to STEM workforce development (NAS, 2016). As more students take introductory science and mathematics courses at community colleges, their success in this lower division coursework is critical in expanding the STEM pipeline (NAS, 2016). However, science and mathematics course enrollment and completion have sometimes been viewed as impediments to student graduation and transfer, valued academic outcomes as students earn required credentials for continuing education and career pathways. There is a need to quantify student academic outcomes and their relationship to graduation and transfer to improve career and advanced higher education readiness for community college students. Success in science and mathematics coursework has implications for both STEM employment and the scientific literacy of a democratic citizenry (Hurd, 1998).

The present study explores academic factors related to student graduation, transfer, and attrition in a community college setting, with particular attention to the role of science and mathematics course completion and performance. Although there is ample literature that has investigated factors that impact graduation and transfer rates, the majority has focused on demographic factors (Bailey, Calcagno, Jenkins, Leinbach, & Kienzl, 2006; Cabrera, Burkum, & La Nasa, 2005; Calcagno, Bailey, Jenkins, Kienzl, & Leinbach, 2008; Lee & Frank, 1990; Hagedorn, Cabrera, & Prather, 2010; McCormick & Carroll, 1999). Additionally, research that explored academic factors has not focused on science and mathematics coursework specifically. This study utilized transcript analysis to examine student course choice and grades of a particular cohort of 3,052 students over a three-year period. Such records have the unique potential to drive progressive policies that increase achievement and degree attainment for community college students (Hagedorn & Kress, 2008). The following research questions were addressed: 1) What is the relationship between science and mathematics course enrollment and completion and graduation and transfer status in a large suburban community college? 2) What science and mathematics academic factors best predict graduation and transfer outcomes when compared to non-completion?

2.2 Theoretical Framework

Theoretical support for this research is based upon the work of Tinto (1975, 1999, 2006), Bean and Metzner (1985), Deil-Amen (2011), and Dougherty, Hare, & Natow (2009). Tinto’s seminal research synthesis (1975) proposed an academic integration model, whereby academic
performance and intellectual development are the primary factors related to attrition. A multitude of studies related to persistence, graduation, and transfer rates have been based upon this model (Kubala, 2000). Tinto (1999) suggested that persistence and graduation are more common in settings where there are high academic standards and clear expectations.

However, Bean and Metzner (1985), Deil-Amen (2011), and Tinto himself (2006) noted that this model is often not applicable to the nontraditional profile that applies to most community college students (AACC, 2016). Although academic integration is important to understand in terms of retention, it needs to be defined and measured differently for community college students. Deil-Amen (2011) studied how community college students perceived their academic integration into their institutions, which, although a central tenet of Tinto’s theory, had not previously been explored for this population. Deil-Amen found that the majority of community college students found little time to engage with the community while on campus. For community college students, connections made during in-class interactions tend to be emphasized over the out-of-class interactions favored for students attending four-year institutions. Therefore, it is important to look at measures of academic success to get a sense of the integration of community college students with their institutions.

This study explored academic factors that affected community college student attrition and graduation. Dougherty et al. (2009) recommended the development of voluntary systems of accountability to address the intent of policy makers to secure better performance results from institutions of higher learning. They recommended several “output” indicators to rate the performance of community colleges. They highlighted the importance of using transfer rates in addition to graduation rates due to the fact that many community college students have no intention of graduating. In the context of this study, academic variables including grades and course completion rates disaggregated for science and mathematics coursework along with required remediation were analyzed in terms of whether the student experienced a positive (graduated or transferred) or negative outcome.

2.3 Background

Role of community colleges in higher education. Community colleges serve a critical role in U.S. higher education, educating 45% of all college students (AACC, 2016; NCES, 2014). Of students enrolled in public four-year institutions in 2011-2012, 35% had spent at least part of their time at a community college (AACC, 2016). Approximately 70% of graduating high school seniors continued their education in college, and 40% of those students enrolled in a community college (Cohen, Brawer, & Kisker, 2013). Students who have not had access to traditional four-year institutions historically have been able to pursue higher education at community colleges due to their open enrollments and lower tuitions (Bailey et al., 2005). Community colleges serve a particularly important role in educating minority populations, as half of all community college students are non-White, while 84% of first-time community college students are non-White (AACC, 2016).

Measures of community college effectiveness. The focus on community college outcomes has evolved from a culture of increased accountability of educational institutions, which has filtered upward from the elementary and secondary levels (Bailey et al., 2006a). The majority of community college revenue is generated by state appropriations, followed by tuition and fees, local appropriations, and state grants and contracts (NCES, 2014). Due to an increased culture of
accountability, community colleges, along with all post-secondary institutions, are pressed to demonstrate the value they provide for their students (Roman, 2007). Several metrics for community college effectiveness are described below since they define key variables for this study.

**Graduation rates.** Due to the wide range of academic preparedness and goals among community college students compared to those at four-year colleges, the effectiveness of community colleges requires a different set of measures. At four-year institutions, the most commonly used method is graduation rate, but this is problematic when considering community colleges. The standard measure for community college graduation rate is a three-year window to obtain a degree, which is 150% of the time expected to complete a degree. The Student Right-to-Know Act requires colleges that receive Title IV funding, which includes the vast majority of institutions, to calculate and publish graduation rates for degree-seeking, first-time, full-time students (Student Right to Know and Campus Security Act [SRK], 1991). As one of the few data sets that has been calculated uniformly between colleges, it has become a useful metric to compare the graduation rates of institutions (Bailey et al., 2005). However, at community colleges it is common for students to start as full-time students but then transition to part-time (Burd, 2004), while this is relatively rare at four-year colleges. Previous research has shown that full-time students were much more likely to persist than part-time students (Mamiseishvili & Deggs, 2013). Although the intent was to leave part-time students out of SRK calculated graduation rates, part-time students are likely included in community college graduation rates thereby artificially lowering them as compared to SRK rates (Bailey, Leinbach, & Jenkins, 2006).

Community college students have shown more mobility than four-year college students (Bailey et al., 2005). SRK data only consider degrees completed at the institution where the student first matriculates, and therefore likely under-reports actual completion rates. The solution to this conundrum is intended to be the SRK transfer rate, but this only counts students that colleges have officially tracked. Community colleges have had a difficult time tracking students once they leave their institution, which has resulted in the SRK transfer data painting an inaccurate picture of actual completion rates by nearly half (Bailey et al., 2005).

More than half of students who entered community colleges have left without obtaining their desired credential (Bailey et al., 2005). Three-year graduation rates at community colleges have typically been slightly above 20% (Schneider & Yin, 2012). Low graduation rates resulted from many factors, such as underprepared students finding the coursework too challenging, students wishing to transfer prior to graduating, part-time rather than full-time attendance, and students who simply needed to complete a certain number of credits and were not degree seekers (Wild & Ebbers, 2002). It is clear that the standard currently being used to measure community college graduation rates does not accurately reflect complexities of community college student enrollment, intention, and completion and needs revision.

**Transfer rates.** Historically, transfer rates from community colleges have been stubbornly low (Adelman, 2005; Hagedorn, Moon, Cypers, Maxwell, & Lester, 2006), although many researchers have questioned their accuracy (Bailey et al., 2005; Banks, 1990; Spicer & Armstrong, 1996). For example, there was growing concern that both the raw number and percentage of students transferring from community colleges to four-year institutions was in decline as far back as the 1970s (Grubb, 1991). More recent statistics indicated that only 37% of
students who graduated high school in 1992 and attended a community college ended up transferring to a four-year school (Adelman, 2005).

It is important to note that calculating transfer rates is difficult and determining the potential pool of transfer students has been particularly problematic. A consistent and universally accepted definition of what constitutes a transfer student has not been developed (Banks, 1990; Bradburn, Hurst, & Peng, 2001; Hom, 2009; Horn & Lew, 2007; Kozeracki, 2001; Spicer & Armstrong, 1996). Spicer and Armstrong (1996) calculated 11 different transfer rates based upon different definitions of groups of transfer students. They found that transfer rates could be calculated as low as 5.3% and 3.6% when considering all students enrolled at two different community college districts in California, to as high as 61.3%, and 40.4% when the pool was significantly narrowed to only those students who indicated that transferring was their goal, were transfer ready, and completed at least 56 credits. Bradburn, et al. (2001) calculated nine different transfer rates varying from a low of 25% for all students to a high of 52% using the most restrictive definition. Horn & Lew (2007) used data from three different cohorts of students enrolled in the California community college system and calculated six different transfer rates that ranged from 15% (least restrictive) to 67% (most restrictive).

For comparison purposes, Spicer & Armstrong (1996) calculated the SRK transfer rate and found that it actually missed 33% of the transfer students from one district and 85% from another because it only considered first-time, full-time students, indicating a large percentage of transfers either started as part-time students or at different institutions. It is interesting to note that SRK data actually included a broader definition of transfer students as it included students who transferred to any other institution, not just those who transferred to four-year institutions. This shows that SRK data can paint a relatively negative portrait of a community college even if the institution is meeting the needs of its students. It is clear that a universal definition of a transfer student needs to be developed to better gauge the effectiveness of community colleges, and transfer must be considered in delineating academic success.

**Student intent.** Another issue with utilizing graduation and transfer rates as measures of community college effectiveness is that not all students enter community college with the intent to graduate or transfer. Students who ultimately transferred to a four-year institution were shown to have self-identified as being interested in transferring from the start (Lee & Frank, 1990). However, Long and Kurlaender (2009) found that among students expressing an intent to complete a baccalaureate degree, students who began at public community college suffered significantly higher rates of dropping out after one, two, and six years as compared to those starting at public four-year institutions.

**Factors predicting student persistence at community colleges.**

**Operational definition of persistence.** For the purposes of this paper, persistence was defined as students who successfully graduated or transferred during the time period studied. As this study used the three-year time period that SRK data used to measure student graduation rate, any students continuing after this time period did not contribute to the graduation rate as calculated for SRK. Likewise, students transferring after this window were not officially counted in the transfer rate. Therefore, although students continuing after the time period of study could be considered persisting, they were not for this study.
**Demographic variables.** There is well-established literature on the connections between demographic variables and community college student outcomes. Studies have found that students who transferred were more likely to be from families with higher socioeconomic standing and less likely to be minority and female (Bailey et al., 2005; Cabrera et al., 2005; Hagedorn et al., 2006; Lee & Frank, 1990; Roman, 2007). Lee and Frank (1990) found that students who successfully transferred closely resembled students who went directly to four-year institutions directly from high school. Long and Kurlaender (2009) found that students starting community colleges were not as well prepared for the rigors of college work coming out of high school and were much more likely to be enrolled part-time when compared to those at selective or nonselective public institutions. Bradburn et al. (2001) reported that using the most restrictive definition of the pool of students in the calculation of transfer rates resulted in inflated numbers of students from higher socioeconomic status and those aged 22 and younger, while underreporting students from lower socioeconomic status and students of color.

Community colleges have been shown to enroll a relatively large percentage of nontraditional students including, but not limited to, minorities, first generation college-students, and delayed enrollment students as compared to four-year institutions (Bailey et al., 2005; Cabrera et al., 2005; Hagedorn et al., 2006; Lee & Frank, 1990; Roman, 2007). Research has found that these non-traditional populations struggle to graduate, which further calls into question the use of graduation rates to assess community college effectiveness (Calcagno et al., 2008).

**Coursework.** Several studies have explored the relationship between coursework and student persistence. Hagedorn et al. (2010) developed a calculator that determines the likelihood of transfer for a student based upon their coursetaking patterns and the institutional characteristics of where they are enrolled. It was their belief that it could be used during advisement to show students how the courses they enrolled in might impact their ability to transfer. The calculator stressed mathematics, English, and science coursework due to the existence of literature that showed these courses were gateways to transfer. Hagedorn & Dubray (2010) showed that mathematics course completion is a barrier to student persistence. The number of science and mathematics courses completed was included in the calculator based upon the work of Cabrera et al. (2005), who showed that the number of science and mathematics courses taken was a strong predictor of transfer.

Hagedorn et al. (2006) explored community college student progression towards transferring in addition to associate’s and bachelor’s degree completion. They found that few students made actual progress towards transferring, even when that was their stated goal. Roughly half of students did not complete a single identified requirement. Physical and biological sciences had the third lowest completion rates after foreign language and English. Students who successfully transferred to four-year institutions from community colleges have been shown to take extra mathematics and science courses (Lee & Frank, 1990). Additionally, it took approximately 9.5 semesters for students to become transfer ready, calling into question whether community colleges truly are two-year schools (Hagedorn, et al., 2006). These coursetaking patterns highlight an additional potential problem of using SRK data to calculate graduation rates.

Studies have examined credit production and how it relates to student outcomes, and two are noted here. Calcagno, Crosta, Bailey, and Jenkins (2007) found that earning 20 non-remedial credits increased graduation rates by 7.6 times for younger (17-20 years of age) students and 4.9 times for older (25-65 years of age) students. McCormick and Carroll (1999) found that first year
credit production was positively correlated to total credit production and degree completion. It is noted that neither of these studies looked specifically at the role of science coursework in credit production.

Many community college students have required remediation upon initial enrollment, particularly in mathematics, reading, and writing (Hagedorn & Dubray, 2010). Some researchers have shown that successful completion of remediation coursework significantly improved student retention in community colleges (Higbee, Arendale, & Lundell, 2005), while others have reached the opposite conclusion (Crisp & Delgado, 2014). Fike and Fike (2008) found that passing a developmental reading course is the greatest predictor of retention, followed by passing a developmental mathematics course and a developmental writing course. One study reported that over 61% of community college students took at least one developmental course, decreasing the time for students to complete credited courses and graduate within three years; these students performed on par with those who did not require remediation (Kolajo, 2004).

_Academic performance_. Another important consideration is academic achievement, represented by grade point averages (GPA). Academic performance is a major predictor of student retention in both two- and four-year colleges. First year GPA has been shown to be a strong predictor of degree completion (McCormick & Carroll, 1999). Research has indicated that for every point increase in GPA for STEM majors, students were more than twice as likely to be retained (Rohr, 2012). Academic success, particularly in science and mathematics, has been associated with transfer of community college students to four-year institutions (Hagedorn et al., 2010).

Although there is ample literature on the connection between coursetaking and persistence, graduation, and transfer, there have been few studies that focused on the role of science coursework. Some studies that mentioned science coursework (Cabrera et al., 2005; Hagedorn et al., 2006; Lee & Frank, 1999) drew few conclusions from that aspect of their study and did not offer policy suggestions based upon them. The connections between science coursework and persistence, graduation, and transfer are gaps in the literature that this research seeks to address.

### 2.4 Methodology

**Research design.** The quantitative research methods employed in this study are part of a non-experimental correlational design (Shadish, Cook, & Campbell, 2002). The purpose was to identify plausible explanations, or relationships among academic characteristics, for two community college student outcomes: graduation/transfer vs. non-completion. Correlational research methods utilize continuous attribute variables in identifying differences among groups (Johnson, 2011). Transcript analysis (Hagedorn & Kress, 2008) was used to discern what variables were related to the ability of a student to graduate and/or transfer successfully. In doing so, models with predictive value were generated to inform policy discussions of the retention and graduation of community college students.

**Context and operational variables.** The study took place at a regional public community college in suburban New York State. In 2014-2015, the institution enrolled 22,374 students, approximately half male and half female. Of those students, 4,618 were first-time students, 1,534 were transfer-in students, 14,066 were continuing their education, and 2,156 were non-degree students. The ethnicities of the student population included: 41% White, 23% Hispanic, 23% Black, 7% Asian, and 5% unknown. The majority of students (76%) were under the age of 24.
The first to second year retention rates of first-time degree seekers was 70% for full-time students and 58% for part-time students. The graduation rate was reported as 6% for two years, or expected completion time; 19% for three years, or 150% of expected completion time; and 27% for four years, or 200% of expected completion time. There were 3,133 associate’s degrees awarded in 2014, with the largest number in Liberal Arts/Sciences (1,683), followed by Business (420), Health Professions (261), Law Enforcement (213), and Personal and Culinary Services (105) (NCES, 2014).

The sample consisted of 3,052 students from a single cohort of Liberal Arts & Science – Humanities & Social Science (A.A.) students who initially matriculated in fall 2011. This degree was by far the most popular on campus, enrolling nearly half of all students. The institution provided de-identified data. The two measured student outcomes were mutually exclusive categories: 1) students who graduated and/or transferred, and 2) students who did not transfer or graduate but enrolled and attempted at least one semester of coursework. Transcript analysis was performed to identify variables that predicted the aforementioned outcomes; this method analyzes academic maps with detailed portraits of students’ experiences in coursework, which is often the only connection such students have to the institution (Hagedorn & Kress, 2008). The independent variables that potentially contributed to these outcomes included the following:

**GPA.** All courses taken starting with fall 2011 and ending with summer 2014 were included in the student’s overall GPA. This was calculated by take the sum of the products of numerical grade and number of credits for each course, and diving by the sum of the credits. Withdrawals and incompletes were assigned a value of 0.0 quality points. Courses where the grade was missing or the course was audited were excluded from the calculation. It is noted that the college did not award “minus” grades. Quality points were assigned according to the school’s standardized grading scale, for example, A=4.0, B+=3.5, B=3.0, etc.

**GPA in science coursework.** GPA in science coursework was calculated in the same manner as the overall GPA. Engineering related courses were included in science courses due to the fact that the Engineering Department is combined with the Physics Department. Science courses were defined to include the following subject areas: Allied Health Sciences, Biology, Civil Engineering Technology, Chemistry, Electrical Engineering Technology, Engineering Science, General Science Studies, Multi-Disciplinary Science, Physical Science, Physics, and Telecommunications Technology. Students withdrew from science courses at a rate of 15.2%.

**GPA in mathematics coursework.** GPA in mathematics coursework was calculated identically to the overall GPA. Courses defined as mathematics courses included computer science related fields due to the fact they were also taught by the Mathematics Department and could satisfy one of the two “mathematics” courses required as part of the associate’s degree. Mathematics courses were defined to include the following subject areas: Computer Processing, Computer Repair Technology, Computer Science, Information Technology, and Mathematics. Students withdrew from mathematics courses at a rate of 17.9%.

**GPA in other academic coursework.** GPA in other academic coursework was calculated identically to the overall GPA. These courses generally included arts and humanities, business, criminal justice, and legal studies. It is noted that courses in Physical Education were not
included in this category since they were considered non-academic. Students withdrew from other academic courses at a rate of 9.2%.

Course completion percentage. The percentage of courses successfully completed was calculated by taking science courses in which a student received a passing grade (A, B+, B, C+, C, D+, D, SP (for mathematics remedial courses)) divided by the total number of courses taken. Withdrawals and incompletes were counted as failing grades. Courses with missing grades and audited courses were excluded from the calculation.

Number of courses taken. The number of science and mathematics courses taken was calculated by counting the number of courses in which a student received any grade (A, B+, B, C+, C, D+, D, F, W, UW, AUD). Courses that a student never attended were excluded from this calculation.

Credit production success rate. The credit production success rate was calculated by dividing the number of credits earned by the number of total credits attempted. It is noted that remedial courses were not included in this ratio, as the credits attached to those courses did not count towards graduation.

Percentage of students requiring mathematics remediation. Once students enrolled, they were required to take a mathematics placement exam consisting of an elementary algebra section and an arithmetic section. Each section consisted of multiple-choice questions and the use of a calculator was permitted. Based upon the individual results of the two sections, students could be placed into two levels of remediation. A student placed into either of the two levels of remediation was included in this percentage. Students who placed into the first level of remediation could take a combined remediation course where successful completion satisfied both levels of remediation. Students who took the first level remediation course alone had to also pass the second level remediation course successfully in order to advance to credit bearing mathematics courses. Students were waived from having to take the entrance exam by having a minimum score on the standardized New York State Integrated Algebra Regents Exam (must have been taken within four years of the application date), Advanced Placement Calculus Exam, or ACT/SAT exams. Students failed remedial mathematics courses at a rate of 39.7%. Of graduating or transferred students, 33% required mathematics remediation, while 53% of non-completers required it.

Percentage of students requiring English remediation. Students were required to take an English placement exam consisting of an essay that was electronically scored. Based upon the score, some students were placed into remedial English (only one level was offered), credit level English, or a hybrid course that met for extra time beyond the credit level English course but awarded college credit upon completion. Students who barely missed the passing grade for the credit level course and the hybrid course had their essays re-graded by a committee of English professors. Students were waived from having to take the entrance exam by having a minimum score on the standardized New York State English Regents Exam (must have been taken within four years of the application date), Advanced Placement English Literature and Composition or English Language and Composition exams, International Baccalaureate English Exam in English
(higher level), or ACT/SAT exams. Of graduating or transferred students, 24% required English remediation, while 35% of non-completers required it.

**Analytical framework.**

Transcript analysis. Transcript analysis was used for this study as it provides a wealth of information for rich analysis (Hagerdorn & Kress, 2008). Several studies have used transcript analysis to determine factors that impacted persistence in terms of graduation and transfer rates (Adelman, 1999; Calcagno et al., 2007; Hagedorn et al., 2010; Hagedorn & Kress, 2008; McCormick & Carroll, 1999). An advantage of using transcript data instead of survey data is that transcripts do not rely upon subject memory and candor (Adelman, 1999). As community college students mainly interact with the institution through academics, they are well suited for transcript analysis (Kubala, 2000).

Statistical analyses. Student outcomes were analyzed with both descriptive and inferential statistics. The main inferential statistical method utilized in this study was binary logistic regression. This method was chosen to compare contributing variables to the two categorical student outcomes after four years: 1) graduation and/or transfer, and 2) students who did not transfer or graduate but attempted at least one semester of coursework. Binary logistic regression is useful in predicting which category a student is most likely to belong and identifying high risk students (Field, 2013; Porchea, Allen, Robbins, & Phelps, 2010), although the model will always be somewhat limited due to omitted variables (Mood, 2010). The group that included students who neither graduated nor transferred was the larger category, representing 53% of the students in the cohort. The dependent variables chosen for this study were all related to science and mathematics coursingaking since these have significant potential to inform policy makers on improving outcomes for community college students. The null hypothesis was that the two possible student outcomes were not statistically associated with the following academic variables: number of mathematics and science courses taken, ratio of courses completed to courses attempted in science and mathematics, and percentage of students requiring remediation in mathematics and English.

Study limitations. Several limitations are acknowledged in the research design. Graduation rates as calculated by SRK data are based upon students who begin as full-time students. However, it could not be determined which students in this sample began as part-time students. Although the removal of students who attempted less than 12 credits (the threshold to be considered full-time) in total was considered, it was decided to leave those students in the study because there was no guarantee that students who attempted more than 12 credits were full-time students during their first semester. The number of students who were known to have started as part-time students was 114 (representing only 3.7% of the total sample), therefore they most likely had a negligible influence on the study.

Data were not obtained for students who continued on after the end of the third year of study. Although some of the students who neither graduated nor transferred continued on at the college into their fourth year, they were included in the non-graduating and non-transfer category as SRK data only represent a three-year window to calculate graduation rates for community colleges. Students who persisted after this window were considered as neither graduating nor transferring even if they ultimately did so.
It is also noted that course classification groupings were large and very diverse courses were included as part of the same category. Engineering courses were included as part of the science category even though they did not satisfy the science general education requirements of the institution.

2.5 Results

The first step of the statistical analysis involved an exploration of the academic variables excluding remediation. Science and mathematics coursetaking was examined by group with descriptive statistics. As shown in Table 1, the majority of students who took at least one science or mathematics course (or both) successfully graduated or transferred from community college. Only 23% of students who did not take science graduated and/or transferred, the same was true for 25% of students who did not take mathematics, and 23% of students who took neither.

Table 1
Success Rate Based upon Science and Mathematics Coursetaking

<table>
<thead>
<tr>
<th>Course Taken</th>
<th>Total Students</th>
<th>Successful Outcome (n)</th>
<th>Graduation and/or Transfer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Take Science</td>
<td>1076</td>
<td>246</td>
<td>23</td>
</tr>
<tr>
<td>Took at Least 1 Science</td>
<td>1976</td>
<td>1193</td>
<td>60</td>
</tr>
<tr>
<td>Did Not Take Math</td>
<td>314</td>
<td>77</td>
<td>25</td>
</tr>
<tr>
<td>Took at Least 1 Math</td>
<td>2738</td>
<td>1362</td>
<td>50</td>
</tr>
<tr>
<td>Did Not Take Science or Math</td>
<td>223</td>
<td>51</td>
<td>23</td>
</tr>
<tr>
<td>Took at Least 1 Science AND 1 Math</td>
<td>1885</td>
<td>1167</td>
<td>62</td>
</tr>
</tbody>
</table>

Science and mathematics coursetaking was also examined in terms of GPA and credit production success rate (Table 2). Average GPA was lower for students who did not take science (1.83) compared to those who did (2.66). The same was true for students who did not take mathematics (1.65) compared to those who did (2.45). Similarly, credit production success rate was lower for those who did not take science (33%) compared to those who took at least one course (70%), which was the same pattern for mathematics (27% vs. 60%, respectively).
Table 2

*Academic Performance Measures Based upon Science and Mathematics Coursetaking*

<table>
<thead>
<tr>
<th></th>
<th>Average Total Earned Credits</th>
<th>Average Cumulative GPA</th>
<th>Credit Production Success Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Take Science</td>
<td>12.1</td>
<td>1.83</td>
<td>33</td>
</tr>
<tr>
<td>Took at Least 1 Science</td>
<td>45.3</td>
<td>2.66</td>
<td>70</td>
</tr>
<tr>
<td>Did Not Take Math</td>
<td>7.2</td>
<td>1.65</td>
<td>27</td>
</tr>
<tr>
<td>Took at Least 1 Math</td>
<td>36.6</td>
<td>2.45</td>
<td>60</td>
</tr>
<tr>
<td>Did Not Take Science or Math</td>
<td>4.1</td>
<td>1.51</td>
<td>21</td>
</tr>
<tr>
<td>Took at Least 1 Science and 1 Math</td>
<td>46.7</td>
<td>2.70</td>
<td>71</td>
</tr>
</tbody>
</table>

Descriptive statistics were generated on the grade-related and course completion variables according to students in each group. The means and standard errors are shown in Table 3. Several findings were evident from these data. In terms of coursework, science course completion was statistically lower than other academic course completion but higher than mathematics course completion. This was true for both groups of students. Graduating and/or transferred students had the highest rate of science course completion (84%) compared to non-graduating non-transfer students (55%). Mathematics course completion was more problematic than science course completion and followed the same pattern by student group: graduating and/or transferred students had the higher rate of mathematics course completion (78%), followed by graduating students who did not transfer (51%). For both groups, science GPA was statistically higher than mathematics GPA, and science and mathematics GPAs were statistically lower than GPAs in other academic courses.

Table 3

*Descriptive Academic Statistics of Student Groups Based Upon Outcomes (N =3052)*

<table>
<thead>
<tr>
<th></th>
<th>Students Who Graduated or Transferred n = 1439 M (SE)</th>
<th>Students Who Did Not Graduate or Transfer n = 1613 M (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRADE POINT AVERAGE DATA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative GPA</td>
<td>2.87 (0.02)</td>
<td>1.94 (0.03)</td>
</tr>
<tr>
<td>Science GPA</td>
<td>2.43 (0.03)</td>
<td>1.30 (0.04)</td>
</tr>
<tr>
<td>Mathematics GPA</td>
<td>2.27 (0.03)</td>
<td>1.29 (0.04)</td>
</tr>
<tr>
<td>Other Academic GPA</td>
<td>2.72 (0.02)</td>
<td>1.57 (0.03)</td>
</tr>
<tr>
<td><strong>COURSE COMPLETION PERCENTAGE DATA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of Science Course Completion</td>
<td>84% (0.01)</td>
<td>55% (0.02)</td>
</tr>
<tr>
<td>Rate of Math Course Completion</td>
<td>78% (0.01)</td>
<td>51% (0.01)</td>
</tr>
<tr>
<td>Rate of Other Academic Course Completion</td>
<td>86% (0.01)</td>
<td>59% (0.01)</td>
</tr>
</tbody>
</table>

The next step was inferential analysis involving a binary logistic regression with possible academic independent variables as defined in the previous section. Students in the cohort were placed into one of two groups using dummy variables in SPSS. Likelihood ratio tests indicated...
which factors in the logistic model were statistically significant. All six of the variables were significant predictors, as indicated in Table 4.

Table 4
Likelihood Ratio Tests for Inclusion of Independent Variables in Logistic Model

<table>
<thead>
<tr>
<th>Academic Variables</th>
<th>$\chi^2$</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Math Remediation Required</td>
<td>71.369</td>
<td>1</td>
<td>0.000***</td>
</tr>
<tr>
<td>2. English Remediation Required</td>
<td>4.516</td>
<td>1</td>
<td>0.034*</td>
</tr>
<tr>
<td>3. Successful Completion Rate of SCI Courses</td>
<td>219.448</td>
<td>1</td>
<td>0.000***</td>
</tr>
<tr>
<td>4. Number of SCI Courses Taken</td>
<td>25.711</td>
<td>1</td>
<td>0.000***</td>
</tr>
<tr>
<td>5. Successful Completion Rate of MAT Courses</td>
<td>91.568</td>
<td>1</td>
<td>0.000***</td>
</tr>
<tr>
<td>6. Number of MAT Courses Taken</td>
<td>14.467</td>
<td>1</td>
<td>0.000***</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .001

Tests for multicollinearity were run to identify variables that confounded the model. All VIF values were below 1.5, indicating acceptable levels of correlation (Belsey, Kuh, & Welsch, 1980). The log likelihood value for the initial model with the intercept only was 2503 whereas the final log likelihood with the six independent variables decreased to 2076, thereby indicating that the ability to predict the outcome variables improved (Mamiseishvili & Deggs, 2013). The Nagelkerke $R^2$ value for the corrected model was 0.28, indicating large effect size and usefulness of the six variables in predicting the variance between student groups. The Pearson chi-square value ($\chi^2 = 427, p < 0.001$) indicated the logistic model fit the data well. The model predicted 74.1% of cases correctly.

The results of the logistic model indicated the variables contributed to each outcome, as shown in Table 5, indicating the null hypothesis was rejected. A significant Wald statistic indicated that the predictor was a significant contributor to the outcome. The odds ratio, $exp(\beta)$, indicated the change of odds of an outcome occurring as the predictor is increased by one unit, indicating the strength of partial effect of individual variables (Field, 2013). Science course completion was a significant predictor, with each one-point rate increase resulting in 4.4 times greater likelihood of graduation and/or transfer; mathematics course completion was an even stronger predictor with an odds ratio of 5.9. Students who did not require mathematics remediation were 1.9 times more likely to graduate and/or transfer, and those who did not require English remediation were 1.3 times more likely to do so. The number of science and mathematics courses taken was significant, with each additional course increasing the odds ratio for graduation and/or transfer to 1.1; the odds ratio for mathematics courses taken was 1.2. Graduating and/or transferring students had more distinguished academic characteristics, and this is reflected in the logistic model. These students had higher course completion rates for science and mathematics, took more science and mathematics courses, and tended not require mathematics and English remediation.
Table 5
Logistic Regression Model of Student Groups Based Upon Outcomes

<table>
<thead>
<tr>
<th></th>
<th>$\beta$ (SE)</th>
<th>Wald</th>
<th>Odds Ratio $\exp(\beta)$</th>
<th>95% Confidence Interval for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math Remediation Required</td>
<td>0.654 (0.120)***</td>
<td>29.696</td>
<td>1.924</td>
<td>1.521 - 2.435</td>
</tr>
<tr>
<td>English Remediation Required</td>
<td>0.273 (0.122)*</td>
<td>5.021</td>
<td>1.314</td>
<td>1.035 - 1.669</td>
</tr>
<tr>
<td>Completion Rate of Science</td>
<td>1.475 (0.157)***</td>
<td>88.203</td>
<td>4.370</td>
<td>3.212 - 5.945</td>
</tr>
<tr>
<td>Courses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Science Courses</td>
<td>0.100 (0.033)**</td>
<td>8.926</td>
<td>1.105</td>
<td>1.035 - 1.180</td>
</tr>
<tr>
<td>Completion Rate of Math Courses</td>
<td>1.780 (0.184)***</td>
<td>94.059</td>
<td>5.932</td>
<td>4.140 - 8.502</td>
</tr>
<tr>
<td>Number of Math Courses Taken</td>
<td>0.143 (0.040)***</td>
<td>13.068</td>
<td>1.154</td>
<td>1.068 - 1.247</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .001

2.6 Discussion and Implications

Science and mathematics coursetaking and measures of academic success. The results of this study have several important findings for community college students, faculty, administrators, and policy makers. First, a more suitable metric for the academic success of community college students is graduation and/or transfer, as opposed to the traditional use of graduation rate only. The composite variable is a more accurate measure since community college students enroll for many different reasons. In using this metric, the evaluation of specific academic variables such as mathematics and science coursetaking can shed light on their respective relationships with academic success. A consistent definition of what constitutes the pool of potential transfers needs to be developed in order to allow for a standard way to measure the effectiveness of institutions.

Mathematics and science coursetaking were examined in this study because of their reputation as more difficult subjects and evidence of their status as gateway courses for transfer. Students may be hesitant to enroll in these courses for fear of failure. These courses may be viewed as impediments to transfer and graduation when students may actually be more likely to reach these goals if they are successful in this particular coursework. The data in this study suggest that taking mathematics and science coursework is positively related to transfer and graduation. Although the nature of this relationship cannot be established as directional or causal, their respective contributions to student outcomes are notable.

These academic variables contributed to student outcomes in different ways. Students who graduated and/or transferred were shown to have higher GPAs and higher rates of science and mathematics coursetaking and completion, and they were less likely to require English and mathematics remediation. This suggests that these students arrived fairly well prepared and achieved academic proficiency in their community college coursework, leveraging their success to pursue higher aspirations. However, it is possible that taking science and mathematics courses contributed to their persistence. The goal of an associate’s degree or transfer to additional higher education represents accomplishment and aspiration. The mental discipline of taking science and mathematics may result in better overall academic performance.

Methods for increasing science and mathematics course completion rates need to be identified and implemented, for example, increasing tutoring opportunities, improving
advisement, and providing professional development for research-based teaching strategies. It was noted that approximately 10% of science courses taken were designed for those intending to major in science or mathematics. As the institution had a separate liberal arts degree designed for those intending to major in mathematics and science, it was not expected to find that large of a percentage of advanced science courses taken. Therefore, it is possible that students taking courses above their abilities could partly explain the low completion rates. This is also supported by the relatively high withdraw rates for science (15.2%) and mathematics (17.9%) courses as compared to other academic courses (9.2%). Additionally, it is not uncommon for students at the community college level to have negative experiences with science and mathematics courses (Hagedorn & Purnamasari, 2012). As students have increasingly shouldered the task of registering themselves through registration management systems, often with limited advisement, it is possible that withdraw and completion rates were impacted by students registering for courses that were not consistent with their learning styles or interests.

Academic self-efficacy and self-concept is often predicated upon successful achievement in prior coursework. Community college students who experience high self-efficacy are more likely to graduate and transfer (Amelink, Artis, & Liu, 2015). It would be interesting to determine whether the timing of science and mathematics courses has an impact on the success rate in those courses. As indicated by the Center for Higher Education Research, Teaching, and Innovation (2012), the first year of college is a particularly important influence in the ultimate student outcome. Consequently, some institutions have created specialized mathematics and other credit-bearing gateway courses meant to be taken during a student’s first year in order to increase graduation and/or transfer (Achieving the Dream Network, 2017). Research has suggested that systemic institution of such policies will positively impact a larger proportion of community college students (Center for Higher Education Research, Teaching, and Innovation, 2012). Adequate academic advisement and support are necessary to maximize student success in such coursework through improved academic integration and persistence.

**Remediation implications.** Students who did not require remediation experienced higher rates of graduation and transfer. If one of the goals of a community college is to have students transfer to pursue a bachelor’s degree, then special attention should be made to improve pre-college preparation and help students perform better on placement exams. At the institution studied, students were only allowed to take the placement exams once per year. A program where students are allowed to re-take a placement test after initially placing into remediation could result in improved outcomes and academic integration. Additionally, little coordination may have existed between the placement testing office and area feeder high schools. An outreach program where the institution helps area high schools understand what will be expected of students on the placement exams could also improve student outcomes.

As seen in other studies, some types of remediation and bridge programs served to improve outcomes for those who did not have adequate pre-college preparation in science and mathematics (Bahr, 2008; Hagedorn & Purnamasari, 2012). Overall, 53% of the students in this study did not transfer or graduate within three years. These students earned the lowest GPAs and completed courses at the lowest percentage in all areas. These students also had the highest rate of remediation. Perhaps having limited academic aspirations could account for their higher rates of remediation, which may have resulted from inadequate preparation at the secondary level or a less serious approach towards the placement tests as compared to students who ultimately transferred. Even with the extra time and resources devoted to these students, these students did
not achieve positive outcomes in terms of graduation within three years. Methods for increasing the success rate of all students in remediation need to be identified and implemented.

2.7 Conclusions

The results from this study indicate that the academic success of community college students may be predicted by mathematics and science coursetaking, but this must be interpreted with caution. Although students completed science and mathematics courses at a statistically significant lower rate than other academic courses and earned statistically significant lower grades in them, it does not appear as if science and mathematics were impediments to students graduating or transferring. Rather, students who performed well in STEM were more likely to graduate and transfer successfully to other institutions. This may suggest that community colleges would serve their students well by providing supports to maximize student enrollment and success in science and mathematics.

Further research is required to examine the relationship between science and mathematics coursetaking and graduation and transfer rates. Although a correlational relationship was identified in this study, causal mechanisms may be explored through multivariable models. For example, factors contributing to graduation and transfer may be explained by structural equation modeling and confirmatory factor analysis with large randomized samples over longer time periods. In this way, the interrelated dependence of graduation and transfer on external constructs may be established in terms of student participation and achievement in gateway mathematics and science coursework. Path models may provide more nuanced tools for administrators and policy makers to develop creative solutions for improved student performance.

A final conclusion of this study is that a universal definition of student success needs to be developed to assess the effectiveness of community colleges. The current method for institutional evaluation, the three-year graduation rate calculated from SRK data, is a misleading standard and needs revision. Output indicators should include metrics that reflect the diversity of student intentions when enrolling. Systemic tracking mechanisms should be employed to follow students once they leave institutions or take breaks in matriculation. A shared national system of student enrollment, objectives, transfer, and graduation would provide more accurate data for informing higher educational reform initiatives. Proactive program administration and student advocacy will contribute to improved STEM participation and performance, increased retention and graduation, and readiness for advanced study and future employment.
Chapter 3

Community College Chemistry Coursetaking and STEM Academic Persistence

3.1 Introduction

The persistence of community college students in science, technology, engineering, and mathematics (STEM) degrees has become a major focus of educational reform efforts in the U.S. (Van Noy & Zeidenberg, 2014). Over 90,000 associate’s degrees in science and engineering disciplines were awarded in 2015, a 135% increase from 2000. Nearly half of all students who earned bachelor’s, master’s, or doctoral degrees in 2008-2013 in STEM-related fields attended a community college at some point during their careers (National Science Board, 2018). However, of all community college students who enrolled in STEM-related degrees between 2003 and 2009, approximately 69% switched to non-STEM fields or left college without earning a credential (Chen, 2013). Community colleges are an important gateway into STEM-related fields yet attrition remains a significant concern for the preparation of an adequate STEM workforce.

Chemistry is a foundational science that is often a required course for STEM undergraduate majors, which suggests its importance for the retention and advancement of college students. Researchers have highlighted the fact that college general chemistry is often a challenging course; the rate at which students receive a grade of D or F in general chemistry has been reported to be over 50% versus 33.4% for other STEM courses (Cracolice & Busby, 2015; Widanski & McCarthy, 2009). Although these findings stressed the importance of general chemistry in the collegiate academic trajectory, the role it plays as a “gatekeeper” course has received scarce study or quantification for community college students. This research explores community college student enrollment and performance in introductory chemistry and how it relates to student characteristics, enrollment in other STEM disciplines, and STEM degree persistence.

3.2 Research Questions

This research will build upon prior work by exploring the chemistry performance of community college STEM majors, and how this relates to demographic and socioeconomic variables and the likelihood of degree change from STEM to non-STEM disciplines. Chemistry enrollment will be compared to biology, anatomy/physiology, and physics to establish the relative importance of chemistry coursetaking in predicting degree change from STEM to non-STEM. The overarching purpose is to examine the significance of introductory chemistry in predicting persistence at a critical juncture in the STEM pipeline. Community college is a point of access for many traditionally underserved students, so this context is particularly important for promoting equitable STEM participation. This study utilized transcript analysis to examine the chemistry performance of four cohorts of community college STEM majors who enrolled over a three-year period (2011-2014). The following research questions were addressed:
1. How does chemistry performance relate to student variables and disciplinary persistence for STEM majors at a community college?

2. How does chemistry enrollment compare to biology, anatomy/physiology, and physics in predicting STEM degree persistence?

3.3 Review of Literature

Role of community colleges in STEM education. Recent policy documents have highlighted the value of community colleges in providing entry to STEM related fields (NAS, 2016; Olson & Labov, 2012). The number of associate degrees awarded in science and engineering experienced a precipitous decline from 62,805 in 2003 to 47,485 in 2007, but has risen each year since then, reaching 85,798 degrees awarded in 2013; an additional 40,699 degrees were awarded in mathematics/computer sciences (National Science Board, 2016). Pathways offered by community colleges include associate of science degrees, traditionally used to transfer to four-year institutions, and associate of applied science degrees (NAS, 2016). STEM-related degrees represented 12.5% of the 1,015,211 associate degrees awarded in 2013. Applied science and engineering technologies degrees accounted for an additional 156,573 degrees awarded, with the majority (74%) awarded in health technologies. Community college chemistry departments meet the needs of these students in terms of foundational instruction – of all chemistry courses offered in these schools, 41% are general chemistry for science majors and 29% are introductory chemistry courses for allied health majors (Ryan, Neuschatz, Wesemann, & Boese, 2003).

Barriers for STEM majors. Students enrolled in STEM degrees often experience academic challenges. Students who attend community colleges, including those in STEM degrees, experience greater rates of remediation, especially in mathematics (Van Noy & Zeidenberg, 2014). This can extend the time to complete a degree (Crosta, 2014). These risk factors often result in more students failing to complete their credentials (Cabrera et al., 2005; Cohen & Kelly, 2019b). The culture and disparities associated with STEM degrees and departments may also have an impact on the retention rate of students, particularly for women, Blacks, and Hispanics who are underrepresented in STEM related fields (National Research Council, 2011). Researchers have identified the common bias that some students are more naturally gifted in STEM as negatively affecting the persistence of underrepresented groups (Crisp, Nora, & Taggart, 2009). Community colleges educate a large share of traditionally underrepresented students in STEM, and therefore serve an important role in reducing inequities in STEM participation (Hagedorn & Purnamasari, 2012).

The role of chemistry as a STEM gateway course. Researchers have sought to identify factors that impact achievement in college introductory chemistry courses, with many focusing on pre-college experiences. Some identified pre-college pedagogical variables that improve college chemistry performance, such as repeating chemistry experiments, spending significant time on stoichiometry, and learning for conceptual understanding (Tai, Sadler, & Loehr, 2005). High school chemistry course-taking has predicted college chemistry performance but not performance in other introductory college-level sciences (Sadler & Tai, 2007). Students’ self-ratings of abilities and academic expectations were shown to predict college chemistry grades,
indicating existing chemistry attitudes and self-efficacy may influence achievement (House, 1995). These factors may be particularly consequential for community college students, many of whom have lower socioeconomic status and tend to take high school chemistry at lower rates (National Science Board, 2016).

Gateway classes are often viewed as academic barriers to success in STEM degrees. It has been shown that performance in gateway courses is an important determinant for the majors students choose to pursue (Crisp et al., 2009; Rask, 2010). In STEM in particular, these courses tend to be ultra-competitive and are sometimes used to “weed out” students who are assumed to lack ability for success (National Academies of Sciences, Engineering, and Medicine, 2016). Grade inflation in non-STEM fields has been shown to siphon off students from STEM majors, especially since students tend to receive lower grades in chemistry and mathematics (Rowe, 1983; Sabot, 1991). An initial lack of success, or a negative experience in the culture of these courses, may result in an increased number of students changing intended degree, especially underrepresented populations (National Academies of Sciences, Engineering, and Medicine, 2016; Crisp et al., 2009).

Recent registration patterns suggested that more students have been taking general chemistry due to its status as a requirement for their majors (American Chemical Society, 2005). Success in general chemistry is particularly important for community college students; students who do not perform well in chemistry and other physical sciences tend to have lower transfer rates to four-year colleges and lower rates of degree completion (Wang, 2016). Villafañe, Garcia, and Lewis (2014) found a significant percentage of college students had to drop chemistry which resulted in their switching to non-STEM majors, although their work did not explore that concept in detail as it was focused on exploring the role of self-efficacy in chemistry. Research in affective domains that influence chemistry performance, though valuable, often involve self-reported measures (House, 1995; Zusho & Pintrich, 2003), and do not provide quantitative evidence for difficulties in STEM persistence that may warrant targeted reforms.

This research employed an analytical lens that explored access to STEM through gateway chemistry course enrollment and achievement in the community college setting. The importance of chemistry is represented by its prominence in STEM access and persistence, while differential levels of readiness for college chemistry are often evident among community college students. Prior research suggested that chemistry plays a high stakes role in STEM outcomes, as represented in Figure 2. This study is one of the first to quantify chemistry-related factors that influence STEM persistence in community colleges.

Figure 2. Chemistry as a STEM gateway course.
3.4 Theoretical Framework: The Role of Chemistry as a STEM Gateway Course

The theoretical basis for this study is based upon research that has suggested introductory science coursework is an essential factor in undergraduate STEM attrition. Seymour and Hewitt’s seminal work, Talking about Leaving: Why Undergraduates Leave the Sciences, explored factors influencing the decisions of STEM undergraduates to switch to non-STEM majors (Seymour & Hewitt, 1997). They identified many structural factors within institutions that contributed to these decisions, such as poor teaching, feeling overwhelmed by the pace and rigor of STEM curricula, harsh grading systems in STEM coursework, and inadequate departmental advisement and support. These factors affected students regardless of academic preparation and potential (Seymour & Hewitt, 1997). In community colleges, interactions within classrooms are the primary connections students have with their institutions (Hagedorn, Maxwell, Rodriguez, Hocevar, & Fillpot, 2000), therefore, examining STEM course experiences and outcomes is insightful in understanding why students pursue other disciplines (Seymour & Hewitt, 1997).

Many policy reports have cited Seymour and Hewitt’s research as a framework for exploring mechanisms to improve retention in STEM majors. Some introductory science courses have been characterized as “de facto gatekeepers” for students with inadequate science background and those who have difficulty adapting to the pace and rigor of college-level science coursework (Labov, 2004, p. 213). Pre-college STEM experiences should include high quality instruction that is vertically aligned with the expectations for college-level success in these disciplines (NRC, 1999). Similarly, university STEM instruction requires student-centered approaches that consider common misconceptions, provide opportunities for active engagement, and emphasize conceptual understanding over rote memorization (NRC, 2003). Misalignment between student pre-college preparation and collegiate academic STEM experiences often results in poor academic performance, dissatisfaction with choice of major, and attrition to other fields (Seymour & Hewitt, 1997; Tyson, Lee, Borman, & Hanson, 1997). This tension often occurs early in the college experience (President’s Council of Science and Technology Advisors, 2012), consequently, a close examination of introductory science courses in specific disciplines is essential for identifying problem areas and potential programmatic improvements that may improve retention in STEM (American Association of Physics Teachers, 2003).

Although studies have explored the persistence patterns of STEM majors in general (Seymour & Hewitt, 1997), or the retention of life science vs. physical science majors (King, 2015), the role of specific science disciplines in STEM attrition is not well understood. STEM coursetaking patterns and performance are frequently aggregated into general mathematics and science categorizations (Chen, 2015). This study builds upon prior research by exploring enrollment and performance in specific introductory science coursework and how these variables relate to STEM persistence. In doing so, reforms in undergraduate education and institutional support might be prioritized in particular science domains.

3.5 Methods

Research design. The quantitative research methods employed in this study are part of a non-experimental correlational design (Shadish et al., 2002). The purpose was to identify plausible explanations for introductory STEM persistence by identifying relationships among chemistry-related academic characteristics and student variables. Correlational research methods
utilize continuous attribute variables in identifying differences among groups (Johnson, 2001). Transcript analysis has been used to discern what variables were related to the ability of community college students to succeed (Hagedorn & Kress, 2008). In employing this method, models with predictive value were generated to inform policy discussions of the retention of community college students in STEM-related degrees, and the role of chemistry course-taking and performance in these decisions. This study was approved by the Nassau County Community College Institutional Review Board (#11262015).

**Context.** The study took place at a regional public community college in suburban New York State. In 2016-2017, the institution enrolled 20,562 students, with approximately the same number of male and female students. Of those students, 4,082 were first-time students, 1,416 were transfer-in students, and 12,852 were continuing their education. The majority of students (11,832) were enrolled full-time while 8,730 were part-time. The ethnicities of the student population included: 7,672 White, 5,340 Hispanic, 4,535 Black, 1,429 Asian, and 1,049 unknown. The largest age group were those 18-24 years, which comprised 71% of all students. The graduation rate was 24% over three years, while the transfer rate was 20%. Females had a significantly higher graduate rate (29%) than males (19%). Graduation rates for ethnic groups were 30% for Whites, 22% for Hispanics, 13% for Blacks, and 21% for Asians. There were 3,460 associate’s degrees awarded in 2016-2017, with the largest number in Liberal Arts and Sciences (1,810), followed by Business and Accounting (379), Health Professions (280), Criminal Justice (210), and Visual and Performing Arts (145) (NCES, 2018). The distribution of students in STEM-related majors and the associated required chemistry courses are summarized in Table 6.

Table 6

<table>
<thead>
<tr>
<th>STEM Related Degree</th>
<th>N</th>
<th>%</th>
<th>Required Science Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Laboratory Technician (A.A.S.)</td>
<td>2</td>
<td>0%</td>
<td>Anatomy &amp; Physiology Sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Either Chemistry Sequence</td>
</tr>
<tr>
<td>Respiratory Care (A.A.S.)</td>
<td>2</td>
<td>0%</td>
<td>Anatomy &amp; Physiology Sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Algebra-Based Chemistry Sequence</td>
</tr>
<tr>
<td>Biology (A.S.)</td>
<td>154</td>
<td>9%</td>
<td>Biology Sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calculus-Based Chemistry Sequence</td>
</tr>
<tr>
<td>Fire Science (A.S.)</td>
<td>73</td>
<td>4%</td>
<td>General Chemistry</td>
</tr>
<tr>
<td>Engineering Science (A.S.)</td>
<td>88</td>
<td>5%</td>
<td>Calculus-Based Chemistry I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Engineering Physics Sequence</td>
</tr>
<tr>
<td>Food and Nutrition (A.S.)</td>
<td>95</td>
<td>6%</td>
<td>Algebra-Based Chemistry Sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>General Biology</td>
</tr>
<tr>
<td>Liberal Arts: Math &amp; Science (A.S.)</td>
<td>1173</td>
<td>69%</td>
<td>Any Science Sequence</td>
</tr>
<tr>
<td>Mortuary Science (A.S.)</td>
<td>7</td>
<td>0%</td>
<td>Chemistry for Applied Science</td>
</tr>
<tr>
<td>Liberal Arts/Science: Early Childhood Ed (A.S.)</td>
<td>20</td>
<td>1%</td>
<td>Any Two Science Sequences</td>
</tr>
<tr>
<td>Liberal Arts/Science: Childhood Ed (A.S.)</td>
<td>43</td>
<td>3%</td>
<td>Any Two Science Sequences</td>
</tr>
<tr>
<td>Liberal Arts/Science: Adolescence Ed (A.S.)</td>
<td>33</td>
<td>2%</td>
<td>Any Two Science Sequences</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1,690</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

The sample consisted of 1,690 first-time students enrolled in STEM degrees in the fall 2011, 2012, 2013, and 2014 semesters. Student outcomes were measured according to the mutually exclusive categories of 1) students who remained in their chosen degree or changed to a different
STEM degree, and 2) those who transferred to a non-STEM degree. Transcript analysis was performed to identify academic and background variables that predicted these outcomes; this method analyzed detailed data points of students’ experiences in coursework, which is often the only connection community college students have to an institution (Hagedorn & Kress, 2008). Transcript analysis is of particular use in this context since it provides an objective academic roadmap of course completion and vertical curricular progression characterized and predicated by chemistry participation and proficiency. Three years of individual student transcripts were analyzed for all students who first matriculated in 2011, 2012, 2013, and 2014.

**Operational student and academic variables.** The independent academic and background variables that potentially contributed to STEM persistence included the following.

**Introductory chemistry performance and coursetaking.** The institution offered several levels of introductory chemistry. There were two separate courses designed for non-STEM majors that could be taken independently. An algebra-based sequence served as a preparatory course for students who needed calculus-based chemistry but had not previously taken chemistry or did not have the required mathematical background. Secondly, a calculus-based chemistry sequence was offered which was required for many STEM-related degrees, such as Engineering Science. Quality points earned in the first course offered of the algebra and calculus-based sequences were tabulated. In cases where students took the first course in both sequences, or took individual courses multiple times, the average quality points earned was used.

Quality points were assigned according to the school’s standardized grading scale, for example, A=4.0, B+=3.5, B=3.0, etc.; the college did not award “minus” grades. Withdrawals and incompletes were assigned a value of 0.0 quality points. Courses where grades were missing or the course was audited were excluded. The average of quality points earned in introductory chemistry was 2.47.

**Introductory anatomy & physiology.** The institution had several health science programs which requires students to take a sequence in anatomy & physiology. The anatomy and physiology courses offered by Allied Health Sciences had no pre-requisites. The average quality points earned in introductory anatomy & physiology was 2.09.

**Introductory biology.** There was only one general college biology course offered for students majoring in STEM. The course had pre-requisites of both high school biology and chemistry, although in practice, lacking either of those courses did not prevent a student from registering for the course. The course focused on cell structure, metabolism, molecular genetics, cell division, and control mechanisms. The average quality points earned in introductory biology was 2.20.

**Introductory physics.** The institution offered three different physics sequences, all of which could be taken by a STEM major. An algebra-based physics course was designed for majors that did not require a calculus-based physics course, or as a preparation for one of the calculus-based sequences for students who had never taken physics or did not have the required mathematical background. One calculus-based sequence was designed for students in engineering majors while the second calculus-based sequence was designed for non-engineering STEM majors. The average of quality points earned in physics was 2.50.
**Gender.** Gender was included as a dichotomous categorical variable. Out of the 1690 students, 938 (56%) were male and 752 (44%) were female.

**Socioeconomic status.** Socioeconomic status was designated as a dichotomous categorical variable. Students were identified as having significant financial need if they qualified for a Federal Pell grant or New York State’s Tuition Assistance Program. Students eligible for TAP came from families who earned $80,000 or less if they were dependents or married couples or had dependents themselves. The limit decreased to $40,000 for married independent students with no dependents, and $10,000 for unmarried independent students with no dependents (New York State Higher Education Services Corporation, 2018). Of the 1690 students, 866 (51%) qualified for financial need while 824 (49%) did not.

**Underrepresented minorities in STEM (URMS).** URMS was included as a dichotomous categorical variable. Students who were reported as Black, Hispanic, Native American, or Hawaiian were included in the URMS population. Of the 1690 students, 753 (45%) were classified as URMS and 937 (55%) were not.

**Analytical framework.**

**Transcript analysis.** Transcript analysis was used for this study as it provides a wealth of information for rich analysis (Hagedorn & Kress, 2008). Student level data allows the disaggregation of outcomes according to student group (Bragg, 2017). An advantage of using transcript data instead of survey data is that transcripts do not rely upon subject memory and candor (Adelman, 1999). As community college students mainly interact with the institution through academics, they are well suited for transcript analysis (Kubala, 2000).

**Statistical analyses.** Student outcomes were analyzed with both descriptive and inferential statistics. The inferential statistical method utilized in this study was binary logistic regression. This method was chosen to compare contributing variables to categorical student outcomes after four years: students who persisted in STEM majors vs. degree changers to non-STEM fields. Binary logistic regression is useful in predicting which category a student is most likely to belong and identifying students at risk of a negative outcome (Porchea et al., 2010), although the model will always be somewhat limited due to omitted variables (Mood, 2010). The dependent variables chosen for this study were all related to STEM degree change with a particular focus on chemistry, since these have significant potential to inform policy makers about considerations for improving STEM outcomes for community college students. The null hypotheses related to the prediction of student outcomes were the following:

1. Chemistry performance does not predict degree change to a non-STEM discipline, when combined in a multivariable model with student ethnicity, gender, and socioeconomic status.

2. Chemistry enrollment does not predict degree change to a non-STEM discipline, when combined in a multivariable model with biology, physics, and anatomy/physiology enrollment.
3.6 Findings

Descriptive statistics on chemistry coursetaking, performance, and degree change.

Chemistry coursetaking. STEM students enrolled in chemistry at a relatively high rate – slightly less than 30% of students enrolled in STEM degrees took either of the two introductory chemistry courses during the first three years of matriculation (Table 7). This rate remained fairly steady among the four cohorts of students. Nearly three times as many students took calculus-based chemistry as compared to algebra-based. A small number of students took both introductory level courses.

Table 7
Number of Students Taking Introductory Chemistry

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Algebra-Based Chemistry</th>
<th>Calculus-Based Chemistry</th>
<th>*Total Who Took Chemistry</th>
<th>% of STEM Majors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>37</td>
<td>84</td>
<td>113</td>
<td>24%</td>
</tr>
<tr>
<td>2012</td>
<td>23</td>
<td>107</td>
<td>127</td>
<td>29%</td>
</tr>
<tr>
<td>2013</td>
<td>24</td>
<td>95</td>
<td>113</td>
<td>26%</td>
</tr>
<tr>
<td>2014</td>
<td>20</td>
<td>91</td>
<td>109</td>
<td>30%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>104</td>
<td>377</td>
<td>462</td>
<td>27%</td>
</tr>
</tbody>
</table>

*Some students took both levels of chemistry

Chemistry performance. Student performance in introductory chemistry revealed a high number of STEM majors who withdrew or earned grades of D or F; the “DFW rate” has often been cited in institutional research studies to identify high-risk courses (Hossler, Kuh, & Olsen, 2001). These grades were not transferable to other institutions, an important consideration for community college students. The DFW rate in chemistry was relatively steady for the first three cohorts at slightly more than one-third of all students, with a noticeable decrease in the last cohort to 23% of all students (Table 8).

Table 8
DFW Rate for Students Enrolled in Introductory Chemistry

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Took Chemistry</th>
<th>DFW</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>121</td>
<td>44</td>
<td>36%</td>
</tr>
<tr>
<td>2012</td>
<td>130</td>
<td>47</td>
<td>36%</td>
</tr>
<tr>
<td>2013</td>
<td>119</td>
<td>40</td>
<td>34%</td>
</tr>
<tr>
<td>2014</td>
<td>111</td>
<td>25</td>
<td>23%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>481</td>
<td>156</td>
<td>32%</td>
</tr>
</tbody>
</table>

Degree change. The rate of degree change for STEM majors who earned a D, F, or W in chemistry is shown in Table 9. Approximately half of these students persisted in their intended majors, while half switched to other fields. Of those who changed majors, an average of 80% changed to non-STEM majors, while 18% changed to other STEM-related degrees. Larger differences were seen in those who earned a C or better in chemistry (Table 10, Figure 3). These
students were more likely to persist in their intended majors (54%) yet more likely to switch to a different STEM degree than those who received a DFW or never took chemistry (16%). This indicates that success in chemistry is associated with persistence in STEM-related fields.

Table 9

*Rate of Degree Change for STEM Majors Who Earned a DFW in Chemistry*

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Did Not Change Degree (% of DFW Group)</th>
<th>Changed to a Non-STEM Degree (% of DFW Group)</th>
<th>Changed to a STEM Degree (% of DFW Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>25</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>2012</td>
<td>19</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>2013</td>
<td>19</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>2014</td>
<td>17</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>80</td>
<td>62</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 10

*Degree Change for STEM Majors Who Earned a C or Better in Chemistry*

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Did Not Change Degree (% of ≥C Group)</th>
<th>Changed to a Non-STEM Degree (% of ≥C Group)</th>
<th>Changed to a STEM Degree (% of ≥C Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>32</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>2012</td>
<td>38</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>2013</td>
<td>53</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>2014</td>
<td>51</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>TOTAL</td>
<td>174</td>
<td>98</td>
<td>53</td>
</tr>
</tbody>
</table>

*Figure 3.* Student STEM persistence after taking introductory chemistry (n=254).

**Multivariable models predicting STEM persistence.**

**Chemistry performance, student demographics, and STEM persistence.** A logistic regression model was generated to test the null hypothesis that chemistry performance and student demographics did not predict change of major to a non-STEM discipline. Tests for
multicollinearity were conducted to identify student variables that affected STEM persistence when combined with chemistry performance. All variance inflation factor (VIF) values were below 1.1, indicating acceptable levels of correlation (Belsey et al., 1980). The Pearson chi-square value ($\chi^2 = 14.517, p < 0.01$) indicated the logistic model fit the data well, predicting 66.9% of the cases. The logistic model indicated that performance in chemistry was a significant predictor of degree change thereby rejecting the null hypothesis, however, none of the demographic factors (gender, socioeconomic status, ethnicity) were shown to be significant predictors of degree change (Table 11). The odds ratio, $\text{exp}(\beta)$, was 0.814 indicating that the better a student performed in chemistry, the less likely she was to change her major. The Nagelkerke $R^2$ value for the model was 0.043, indicating a small to medium effect size and usefulness of the four variables in predicting the variance between student who changed major and those who persisted. This indicates that regardless of background, students who perform better in introductory chemistry were more likely to persist in STEM majors.

Table 11

<table>
<thead>
<tr>
<th></th>
<th>$\beta$ (SE)</th>
<th>Wald</th>
<th>Odds Ratio Exp($\beta$)</th>
<th>95% Confidence Interval for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry Performance</td>
<td>-.205 (.068)**</td>
<td>9.101</td>
<td>0.814</td>
<td>0.713 0.931</td>
</tr>
<tr>
<td>Gender</td>
<td>.227 (.204)</td>
<td>1.235</td>
<td>1.255</td>
<td>0.841 1.873</td>
</tr>
<tr>
<td>Socioeconomic Status</td>
<td>-.052 (.207)</td>
<td>0.064</td>
<td>0.949</td>
<td>0.633 1.423</td>
</tr>
<tr>
<td>URM in STEM</td>
<td>-.332 (.210)</td>
<td>2.503</td>
<td>0.718</td>
<td>0.476 1.082</td>
</tr>
</tbody>
</table>

**$p < .001$**

The probability of changing to a non-STEM major based upon chemistry performance is also represented by the graph in Figure 4. As chemistry performance improved, students were less likely to switch out of STEM disciplines, with students earning an average of 4.00 quality points half as likely to switch to a non-STEM major as those who earned zero quality points. The simple regression model indicated chemistry performance explained 58% of the variance in degree change to non-STEM fields ($R^2 = .58$).
Figure 4. Probability of changing to a non-STEM major based on chemistry performance.

**Academic coursetaking and STEM persistence.** A logistic regression model was run to test the null hypothesis that STEM coursetaking in individual disciplines did not predict change of major (Table 12). Multicollinearity tests showed all VIF values were below 1.3. The Pearson chi-square value ($\chi^2 = 100.826, p < .001$) indicated the logistic model fit the data well, and the model predicted 62.7% of the cases. Chemistry coursetaking was the only significant predictor of degree change to a non-STEM discipline, with students 2.3 times more likely to switch to non-STEM majors if they enrolled in chemistry. Thus, the null hypothesis was rejected. Conversely, biology and anatomy/physiology coursetaking were significant predictors of students remaining in STEM majors. Physics enrollment was not a significant predictor of either outcome. The Nagelkerke $R^2$ value was 0.078, indicating small to medium effect size and usefulness of the academic variables in predicting variance in STEM persistence. This model indicates that taking introductory chemistry was associated with a greater likelihood of a student changing to a non-STEM major, while taking introductory anatomy & physiology and biology were associated with students remaining in STEM. This result provides evidence that chemistry plays an important role as a gatekeeper course for STEM majors, often diminishing retention.

<table>
<thead>
<tr>
<th>Course</th>
<th>$\beta$ (SE)</th>
<th>Wald</th>
<th>Odds Ratio $\exp(\beta)$</th>
<th>95% Confidence Interval for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>.838 (.134)***</td>
<td>39.20</td>
<td>2.313</td>
<td>1.779 – 3.001</td>
</tr>
<tr>
<td>Physics</td>
<td>.207 (.150)</td>
<td>1.913</td>
<td>1.230</td>
<td>0.917 – 1.649</td>
</tr>
<tr>
<td>Biology</td>
<td>-.360 (.125)***</td>
<td>8.271</td>
<td>0.698</td>
<td>0.546 – 0.892</td>
</tr>
<tr>
<td>Anatomy/Physiology</td>
<td>-.993 (.133)***</td>
<td>55.75</td>
<td>0.371</td>
<td>0.286 – 0.481</td>
</tr>
</tbody>
</table>

**p < .001***
3.7 Limitations

This study has several limitations. As the analysis was correlational and not randomized and controlled, it was difficult to establish causation. The results indicated a relationship between introductory chemistry and students changing to non-STEM degrees, not that chemistry was the cause of those degree changes. As the data originated from a single community college, it may not be generalizable to other community colleges, especially those not suburban in nature. Instructor variables, such as pedagogical strategies and grade distributions, were not considered. Student pre-college preparedness was not factored into the study. Examining differences in teaching style and previous student preparation may have identified more nuanced interpretations.

3.8 Implications for Chemistry Education

The results of this study suggest several key implications for community college chemistry education. Data revealed a high DFW rate in chemistry, which often preceded degree changes to non-STEM majors. This indicates community college students were often encountering significant difficulty in succeeding in introductory chemistry. Interestingly, students who received a C or higher in introductory chemistry changed degrees at close to the same rate as those who received a DFW, but many of the former group changed to a different STEM major. Having STEM-focused Liberal Arts students find success in chemistry may be a way to increase retention in STEM majors overall.

Introductory chemistry has a high relative importance as a gateway course in the community college context. The results demonstrate that performance in introductory chemistry is a predictor of persistence in a STEM degree, while student characteristics are not predictive. This finding contradicts previous research that reported SES, gender, and ethnicity were factors that negatively impacted student outcomes (Cabrera et al., 2005; Chen, 2013; Wang, 2012). The present study suggests that students of any background can be successful in chemistry, however, chemistry performance is a necessary achievement early in the community college pipeline. Research has suggested some students require early academic support and intervention to reach gateway milestones (Calcagno et al., 2007); institutional interventions aimed at increasing success rates in chemistry may be particularly effective in improving student outcomes for STEM majors (Rowe, 1983), as well as promoting diversity in these fields. Decreasing attrition in undergraduate STEM majors has been cited as a key strategy for maintaining a vibrant talent pool of STEM professionals to meet projections for economic needs (President’s Council of Science and Technology Advisors, 2012).

The findings also indicate introductory chemistry enrollment is the main predictor of attrition in STEM while introductory biology and anatomy and physiology enrollments were predictors of persistence; physics coursetaking was neither related to STEM persistence nor attrition. The majority of degrees requiring anatomy and physiology were in the allied health sciences, which did not require students to take chemistry, and students were likely to persist; this may have been due to the competitive nature of specific program admissions. Students who enrolled in biology were interested in pre-medical or other biological sciences tracks which typically required students to take chemistry. Since students routinely took both biology and chemistry, it is notable that biology served as a predictor of remaining in STEM while chemistry had the opposite effect. Although physics is often considered a difficult science, enrollment in the course did not predict
degree change. This suggests chemistry is the most prominent gateway foundational STEM course, and enrollment and poor performance in chemistry often has negative consequences in terms of STEM persistence. This predictive framework is summarized in Figure 5.

**Figure 5.** Chemistry enrollment and performance as a quantified gateway to STEM persistence.

These findings highlight the importance of introductory chemistry as a STEM gateway course and may present avenues for targeted academic interventions in order to reduce attrition in STEM majors. For example, Schmid et al. showed that a one-week bridging course was successful in improving the outcomes of students with no previous chemistry experience (Schmid, Youl, George, & Read, 2012). Implementation of similar courses at community colleges may be able to improve outcomes thereby reducing attrition in STEM majors. Rowe suggested strategies to diminish the cognitive load associated with the extensive new knowledge presented in typical chemistry curricula (Rowe, 1983). The incorporation of student-centered teaching practices that move away from teacher-centered knowledge transmission has been shown to improve student motivation and learning in science (Daempfle, 2003).

This research also calls into question what role, if any, academic advisement has in student outcomes. Community college students are often not socially integrated and do not discuss course choices with faculty and peers (Kubala, 2000). The institution where this study occurred utilized a course management system that allowed students to register for courses without academic advisement. It is possible that students registering for inappropriate chemistry coursework could be a factor in STEM attrition. Institutions may be able to improve outcomes by explicitly communicating which chemistry courses serve as preparation for higher level courses and specific career aspirations.

Further research is required to examine the relationship between community college chemistry coursetaking and STEM persistence. Such studies might examine large scale data sets from a cross-institutional sample, chemistry pedagogy in community college classrooms, and academic resilience in challenging introductory STEM coursework. This work may provide insights into interventions to lessen the impact of chemistry enrollment on STEM attrition in diverse community college contexts. Chemistry coursetaking is a foundational gateway, and
community colleges must explore ways in which their students will maximize performance and persist in STEM.
Chapter 4

Mathematics as a Factor in Community College Science Performance, Persistence, and Degree Attainment

4.1 Introduction

Community colleges serve a vital role in the education of STEM majors in the U.S. Almost half of all students who completed a STEM degree (bachelor’s, master’s, or doctoral) during the years 2008-13 received at least part of their education at community colleges; between 2000 and 2015, the amount of STEM-related associates degrees awarded increased 135% to over 90,000 per year (National Science Board, 2018). Community colleges also serve as an important entry point into higher education for traditionally underrepresented populations in STEM, thereby promoting equitable STEM participation (AACC, 2016; Bailey et al., 2005; Hagedorn & Purnamasari, 2012). Several recent policy documents have highlighted the importance of community colleges in the preparation of students for the STEM workforce (NAS, 2016; National Governors Association, 2011, National Science Board, 2018, National Research Council, 2011). However, most research to date on STEM pipeline persistence from academia to the workforce has focused on four-year colleges, which limits understanding of the potential of two-year pathways in diversifying STEM participation (Wang, 2016).

Community colleges have many advantages for traditionally underrepresented groups of students pursuing STEM careers, in that they are generally affordable and provide more varied higher education options than four-year institutions (AACC, 2016). However, there have been chronic issues regarding the vertical alignment of community college STEM education with workforce demands and advancement to baccalaureate institutions (Hoffman, Starobin, Laanan, & Rivera, 2010; Olson & Labov, 2012). Academic preparation and STEM coursetaking patterns have provided an insightful analytical lens for exploring community college outcomes such as STEM degree attainment and transfer to four-year institutions (Jackson, Starobin, & Laanan, 2013; Porchea et al., 2010; Wang, 2012). An important consideration in STEM post-secondary coursetaking is the role of mathematics as a gateway to STEM success and persistence, particularly in the context of the two-year college as an alternate pathway to STEM careers (President’s Council of Advisors on Science and Technology, 2012). However, much of the prior research on this issue examined remedial mathematics performance only (Bahr, 2012), pre-transfer and/or graduation credit production in all subjects (Hagedorn et al., 2010; Hagedorn, & Lester, 2008; Wang, 2016), and demographic differences in STEM degree attainment (Hagedorn & Dubray, 2010; Maxwell et al., 2003). Few studies have explored initial mathematics coursetaking at all levels, specifically in community college contexts, and its relationship to student background characteristics and STEM academic outcomes, including achievement, persistence, and graduation and/or transfer to four-year institutions.

This research builds upon prior work by exploring the initial mathematics enrollment and performance of STEM majors, and how this relates to demographic and socioeconomic variables and the likelihood of degree change from STEM to non-STEM disciplines, graduation and
transfer rates, attrition from college, science performance, and credit production. The overarching purpose was to examine the significance of mathematics preparedness and student characteristics in predicting persistence at a critical juncture in the STEM pipeline. This study used transcript analysis to examine the mathematics performance of four cohorts of community college STEM majors who initially enrolled over a three-year period (2011-14). The following research questions were addressed: For community college STEM majors, how do student characteristics, mathematics placement, and mathematics performance relate to the following academic variables: 1) disciplinary persistence; 2) graduation and/or transfer rates; 3) enrollment attrition; 4) science performance; and 5) credit production rate?

4.2 Theoretical Framework

The theoretical framework for this study was based upon research identifying several constructs related to the community college context, academic persistence, and science and mathematics self-efficacy and performance. Community colleges are unique institutions, in that they are typically open access and serve more diverse populations than four-year colleges (Cohen et al., 2014). The academic pathways of STEM majors in community colleges are characterized by the logistical complexities of pursuing a variety of desired outcomes (e.g., transfer to four-year college, workforce preparedness, adult education) (Hagedorn, Cypers, & Lester, 2008; Kane & Rouse, 1999). Bahr (2013) proposed the issue of community college student achievement and persistence should be explored via a “deconstructive” approach, whereby the focus is upon the academic process to reach a desired outcome as opposed to the outcome itself. Student academic behaviors (identified through transcripts) that commence with initial enrollment and proceed sequentially throughout matriculation often reveal the milestones and barriers that contribute to eventual outcomes (Calcagno et al., 2007). Research on student pathways through community colleges has been scarce, particularly in terms of the early stages of transition to college, participation in developmental learning, and achievement in credit-bearing coursework (Goldrick-Rab, 2010). Student learning evidenced by coursetaking and performance indicators may inform institutional policies and interventions to improve academic outcomes (Bahr, 2013; Leinbach & Jenkins, 2008).

Sociopsychological theories of academic behaviors that lead to desired outcomes also informed this study. Social cognitive theory suggests that outcome expectations involve the belief that specific behaviors will result in a designated consequence (Bandura, 1986). Researchers further explored this construct in relation to the career development process; Lent, Brown, and Hackett (1994) proposed social cognitive career theory, whereby academic and career agency are influenced by self-efficacy (confidence in performing given tasks), setting immediate goals and engaging in processes to achieve them, and formulating desired performance outcomes. Students’ self-efficacy and optimism in the face of challenges have been shown to be key factors in academic success and outcome expectations, particularly in the first year of college (Chemers, Hu, & Garcia, 2001; Lent, Brown, & Larkin, 1984), and grades evidenced by transcripts often influence students’ confidence in their future academic and career goals (Hagedorn et al., 2008; Hagedorn & DuBray, 2010; Wang, 2013).

Researchers have reported that mathematics self-efficacy beliefs and outcomes expectations predicted both academic achievement and choice of STEM major (Hackett & Betz, 1989; Lent, Lopez, & Bieschke, 1991; Lopez, Lent, Brown, & Gore, 1997; Wang, 2013), and STEM performance and credit production have positively influenced STEM baccalaureate degree
attainment (Wang, 2015). Mathematics achievement has been identified as a key prerequisite and barometer of performance in many disciplines, but is particularly important in STEM (Chen, 2013; Lent et al., 1991), therefore, examining its relationship to particular outcomes in the academic process is an important facet of deconstructive analysis. Other studies have examined the role of student characteristics in applying social cognitive career theory to STEM persistence, which may inform targeted interventions for diverse populations (Shaw & Barbuti, 2010; Wang, 2013). Exploring these issues in the community college context is critical given the unrealized potential of such institutions in strengthening the STEM pipeline for traditionally underrepresented students (Bahr, Jackson, McNaughtan, Oster, & Gross, 2017; Wang, 2015). Figure 6 summarizes the application of deconstructive analysis in understanding the role of contextual variables and academic behaviors in predicting STEM outcomes for community college students.

![Deconstructive Analysis Model](image)

**Figure 6.** Theoretical model for exploring the role of mathematics and student demographics in STEM performance and persistence.

### 4.3 Review of Literature

**Measures of community college effectiveness.** Various metrics have been employed for defining and measuring community college effectiveness, although there has not been agreement on the best model. The Student Right to Know and Campus Security Act of 1990 (SRK, 1991) requires institutions to publish graduation rates in order to receive Title IV funding. This act established a six-year window (150% of the expected time for degree completion) for students to graduate with a bachelor’s degree and a three-year window for an associate’s degree. However, graduation rate alone is not widely considered to be the best measure of community college effectiveness (Bailey et al., 2005). Community college students tend to come from non-traditional backgrounds and they generally take longer to complete degrees and have lower graduation rates (AACC, 2016). Additionally, they enroll for a variety of reasons, including workforce development or completing pre-requisites for a transfer program, without graduation as their primary goal (Bahr, 2013). Several studies have discussed the importance of arriving at a universal methodology for calculating transfer rates, in addition to graduation rates, so they may be utilized as a more inclusive measure of community college effectiveness (Cohen & Kelly,
STEM persistence in community colleges. Research has identified many factors that influence the persistence of STEM majors at community colleges. Students enrolled in two-year colleges tend to be older, work more, and have greater familial responsibilities; these factors have been shown to decrease persistence (Calcagno et al., 2007; Wang, 2012). A large percentage of community college students have attended on a part-time basis, or experienced breaks in their enrollment, which increased the time it took to complete a degree and negatively impacted persistence (Bailey et al., 2005; Crosta, 2014). Developmental requirements, particularly in mathematics, and credit production rate have also been shown to be key factors in predicting persistence and degree completion (Calcagno et al., 2007; Hagedorn et al., 2010; Hagedorn et al., 2006; Hagedorn & Purnamasari, 2012).

The culture associated with STEM degrees and departments may have an impact on the retention rate of students (Cabrera et al., 1999; Perez, Cromley, & Kaplan, 2014; Ramsey, Betz, & Sekaquaptewa, 2013; Reid & Radhakrishnan, 2003). Fields traditionally dominated by one gender or culture may convey the message that only certain genders and/or cultures are suited particular fields (Cech & Waidzunas, 2011; Crisp et al., 2009; Dai & Cromley, 2014; Leslie, Cimpian, Meyer, & Freeland, 2015; NAS, 2016; Smith, Lewis, Hawthorne, & Hodges, 2013). Students who have not experienced a sense of community or belonging have been more likely to leave STEM (Jackson et al., 2013; Nguyen & Ryan, 2008; Smith et al., 2013); women, in particular, have cited isolation as a prime reason for leaving STEM (Brainard & Carlin, 1998; Hewlett, Luce, & Servon, 2008; Kelly, 2016). Research has suggested that students found a more welcoming culture and supportive environment at community colleges compared to four-year institutions, highlighting the promise of community colleges in narrowing the STEM participation gap among underrepresented groups (Jackson & Laanan, 2011; Packard, Gagnon, LaBelle, Jeffers, & Lynn, 2011; Starobin & Laanan, 2008).

Influence of pre-college coursework on enrollment in STEM. There has not been consensus as to which pre-college academic factors have been most predictive of students enrolling in STEM degrees. Research has found student interest in STEM has been an important predictor of matriculation in STEM (Federman, 2007; Maltese & Tai, 2010, 2011; Wang, 2013), while others have focused on student cultural characteristics, for example, those more likely to choose STEM were from families who stressed high academic aspirations and achievement (Schneider, Swanson, & Riegle-Crumb, 1998). Some studies identified the number of courses taken in science and mathematics as a significant predictor of enrollment in STEM (Maltese & Tai, 2011; Maple & Stage, 1991; Wang, 2013), whereas other literature specified that enrollment in advanced science and mathematics coursework (for example, physics, pre-calculus, and calculus) best predicted enrollment in STEM degrees (Burkam & Lee, 2003; Federman, 2007; Trusty, 2002). Advanced mathematics coursework taken at the high school level has been shown to lead to better outcomes at the collegiate level (Gayles & Ampaw, 2011; Tyson et al., 2007). Students who took advanced coursework in high school typically enrolled in higher levels of mathematics upon entry in college, which positively predicted student outcomes (Chen, 2013; Tyson et al., 2007).

Role of mathematics in student outcomes. Gateway classes in science and mathematics have also been viewed as potential roadblocks to success in STEM degrees (President’s Council
of Advisors on Science and Technology, 2012). These courses tend to be competitive and have sometimes been used to “weed out” students who were assumed to lack the ability to be successful in STEM fields (NAS, 2016). An initial lack of success in one of these courses, or a negative experience in the culture of these courses, may result in an increased number of students choosing to not persist in the degree, especially for underrepresented populations (Cohen & Kelly, 2019a; Chen, 2013; Crisp et al., 2009; NAS, 2016). Mathematics courses may be particular roadblocks, as one study showed that 25% of students in Calculus I received a D, F, or W, while another 23% received a C, potentially conveying the message that they were not capable of handling more advanced work (Hagedorn & DuBray, 2010). This effect may be magnified at community colleges where many students have been required to take developmental courses, college algebra, and/or pre-calculus, which have been not been shown to be effective in preparing students for calculus (Bressoud, Carlson, Mesa, & Rasmussen 2013). In one study, only half of the students who took pre-calculus in college moved onto calculus I and, out of those that did, only 40% enrolled in calculus II (Herriott & Dunbar, 2009). Past performance also has the potential to impact affective domains, for example, Dika & D’Amico (2016) found that students who perceived themselves as being prepared in mathematics were significantly more likely to persist in STEM degrees than those who did not.

Several studies examined the impact that developmental requirements in mathematics have had on student outcomes. Van Noy & Zeidenberg (2014) found that developmental requirements negatively impacted STEM degree completion rates. Bahr (2012) found that those who were successful in their first attempt in developmental mathematics were more likely to persist at their institutions, whereas students who delayed taking developmental mathematics were more likely to suffer attrition. An added complication is the fact that several studies found that placement tests were not particularly adept at placing students into the correct level of mathematics, which has the potential to negatively impact student outcomes (Armstrong, 2000; Scott-Clayton, 2014). California requires multiple measures to be used in the placement as opposed to a single placement test score; research has suggested that using multiple measures (specifically high school GPA and prior math background) resulted in more students being placed into the correct level of mathematics and increased registrations in advanced mathematics courses without harming outcomes (Ngo & Kwan, 2015).

The impact of course selection and advisement on student outcomes. Research has indicated that structured degree pathways and academic advisement impact persistence and completion rates of community college STEM majors. Rosenbaum, Deil-Amen, and Pearson (2006) explored differences in “organizational procedures” between community colleges and four-year institutions and found that structured degree paths improved persistence and graduation rates by providing students with clear course sequences to follow. Moore & Shulock (2011) found that students who registered for and completed nine credits in required courses during their first year of study were twice as likely to complete their credentials or transfer than those who did not. This idea was further supported by Scott-Clayton (2011), who suggested community college student achieved better outcomes in programs that were tightly structured and maximized the likelihood that students would adhere to suggested course sequences. Advisement was shown to be of particular importance at community colleges where many students must complete developmental credits that do not count towards graduation, some courses count towards graduation requirements for some degrees but not others, and certain courses may not be accepted by transfer institutions (Scott-Clayton, 2011).
Rosenbaum et al. (2006) also highlighted deficiencies in the registration process where community college students faced long lines for advisors even though they could register online, and confusion as to what to do if the courses they needed were not available. One national survey showed that less than a quarter of community college students have an assigned advisor who can answer questions and map out coursework progression (Center for Community College Student Engagement, 2010). A lack of advisors knowledgeable in STEM degree pathways may result in students not taking the courses that optimize opportunity to transfer (Packard, 2011). Community college students typically have not experienced the family and peer networks needed to overcome these obstacles as much as students attending four-year colleges (Bailey et al., 2005). Community college students often need to seek advice actively and institutions have experienced difficulty identifying and assisting struggling students (Scott-Clayton, 2011).

4.4 Methods

Research design. A non-experimental correlational design was utilized as the quantitative research method for this study (Shadish et al., 2002). The purpose was to explore relationships between initial mathematics enrollment and performance and student variables to identify potential explanations for persistence in STEM in a community college context. Correlational research methods are able to identify differences amongst groups through the utilization of continuous variables (Johnson, 2001). Additionally, several academic and demographic categorical variables were explored to determine the relationship they had to STEM outcomes. This multivariate and longitudinal observational study examined existing data that were not randomized, which has potential for higher external validity than experimental studies although confounding variables sometimes lessen internal validity (Cooley, 1978). Transcript analysis determined which variables predicted the persistence of community college students and graduation with a STEM degree or transfer without changing to a non-STEM degree; this method has been employed by many researchers in community college contexts since transcripts provide an accurate academic history of developmental progressions (Hagedorn & Kress, 2008; Wang, 2016; Zeidenberg & Scott, 2011). Models were generated in order to predict which students would have the highest performance in their STEM coursework and successfully complete the largest percentage of their credits in order to inform policy discussions of how to retain community college students in STEM majors.

Context. The study took place at a regional public community college in suburban New York State. The institution had an enrollment of 20,562 in 2016-17 with nearly equal percentages of male and female students; 4,082 were newly enrolled, 1,416 were new transfer students, and 12,852 were continuing in their second or later semester. There were 11,832 full-time students while 8,730 were enrolled part-time. The institution enrolled a large number of minorities traditionally underrepresented in STEM with 5,340 Hispanic and 4,435 Black students. There were 7,672 White students enrolled, 1,429 Asian, and 1,049 of unknown ethnicity. The vast majority of students (71%) were between 18-24 years of age. The institution reported a three-year graduation rate of 24% versus 33% for community colleges nation-wide and a transfer rate of 20% (NCES, 2018). There were 3,460 associate’s degrees awarded in 2016-17, with the largest number in Liberal Arts and Sciences (1,810), followed by Business and Accounting (379), Health Professions (280), Criminal Justice (210), and Visual and Performing Arts (145) (NCES, 2018). The largest STEM-related degree at the institution was the Liberal Arts: Mathematics& Science (A.S.) degree in which 78% of the study population were enrolled. The
Associate of Science in Biology degree accounted for 10% of the students with Engineering Science (A.S.) and three Associate of Science Teacher Education degrees accounting for the rest (Table 13). All STEM degrees require students to complete two courses in advanced mathematics, either pre-calculus and calculus I or calculus I and calculus II depending upon initial mathematics placement.

Table 13
STEM Related Majors and Required Mathematics Courses

<table>
<thead>
<tr>
<th>STEM Related Degree</th>
<th>n</th>
<th>%</th>
<th>Required Mathematics Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology (A.S.)</td>
<td>154</td>
<td>10</td>
<td>Pre-Calculus and Calculus I or Calculus I and Calculus II</td>
</tr>
<tr>
<td>Engineering Science (A.S.)</td>
<td>88</td>
<td>6</td>
<td>Calculus I, Calculus II, Multivariable Calculus, and Elementary Differential Equations</td>
</tr>
<tr>
<td>Liberal Arts: Mathematics &amp; Science (A.S.)</td>
<td>1173</td>
<td>78</td>
<td>Pre-Calculus and Calculus I or Calculus I and Calculus II</td>
</tr>
<tr>
<td>Liberal Arts/Science: Early Childhood Ed (A.S.)</td>
<td>20</td>
<td>1</td>
<td>Calculus I and Calculus II</td>
</tr>
<tr>
<td>Liberal Arts/Science: Childhood Ed (A.S.)</td>
<td>43</td>
<td>3</td>
<td>Calculus I and Calculus II</td>
</tr>
<tr>
<td>Liberal Arts/Science: Adolescence Ed (A.S.)</td>
<td>33</td>
<td>2</td>
<td>Calculus I and Calculus II</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1511</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Prior to enrollment, students were required to take an entry-level mathematics placement test unless they had achieved a minimum grade on the mathematics section of the SAT or ACT, achieved a minimum grade on the Integrated Algebra Regents Exam that all high school students in New York State were required to take, achieved a minimum grade on the AP Calculus or IB Mathematics exam, or had a transferrable grade in a college-level algebra & trigonometry (or above) course. If they did not achieve the required score they were placed into one of two levels of developmental mathematics. Placement into the first level required the students to complete both levels or take a course that was a combination of both developmental courses. Students who achieved the required score to place out of developmental mathematics were then able to take a college-level placement test to place into pre-calculus or calculus I. Students who were waived from the entry-level placement were required to take the college-level placement exam unless they achieved the minimum score on the AP Calculus or IB Mathematics exam, or had a transferrable grade in a college-level algebra & trigonometry (or above) course. The institution used a course management and registration system with strict controls to ensure students could not register for a credit-bearing mathematics course if they placed into developmental mathematics; students could not register for a mathematics course for which they did not satisfy the pre-requisites.

The study sample consisted of 1,511 first-time students enrolled in STEM degrees who first matriculated in 2011, 2012, 2013, and 2014. A small percentage (n=180, 12%) of students began as part-time students; it was not possible to track whether they continued as part-timers or eventually switched to full-time status or vice versa. Student outcomes were measured according to the mutually exclusive categories of students who graduated or transferred versus those who did not, students who persisted in a STEM-related degree versus those who changed to a non-STEM degree, and students who persisted at the institution versus those who left without completing their degrees or transferring. Additionally, science performance and credit production
rates were disaggregated based upon initial enrollment in mathematics. Transcript analysis was utilized to determine which demographic and academic variables predicted these outcomes.

**Operational student and academic variables.** The independent academic and background variables that potentially contributed to graduating or transferring, persisting in STEM, and persisting at the institution included the following.

**Initial mathematics enrollment.** Initial mathematics enrollment was divided into three levels: 1) developmental, 2) algebra & trigonometry, and 3) advanced mathematics, similar to the classifications defined by Burkham & Lee (2003). Students were defined as beginning at the developmental level if they were required to take any of the developmental mathematics courses previously described. Students were defined as starting at the algebra & trigonometry level if they initially enrolled in the institution’s four-credit algebra & trigonometry course. Students were defined as beginning at the advanced level if they initially enrolled in pre-calculus or calculus.

**Performance in mathematics and science.** Performance in mathematics was defined by the average quality points a student earned in all of their mathematics courses. Quality points were based upon the institution’s standardized grading scale where an A=4.0, B+=3.5, B=3.0, etc.; the institution did not award “minus” grades. Withdrawals were assigned a value of 0.0 quality points. Audited and missing grades were excluded from the sample. Performance in science was calculated using the same methodology as performance in mathematics.

**Credit production rate.** Credit production rate was defined as the percentage of credits attempted that were successfully completed. It was calculated by dividing the total credits attempted by the total credits earned.

**Change of major to a non-STEM degree.** Change of major out of STEM was included as a dichotomous categorical variable with “no” and “yes” being the two possible outcomes. All majors other than those listed in Table 1 were defined as non-STEM majors. A student who changed from one STEM major to another STEM major was categorized as “no.” The institution offered several Associate of Applied Science degrees in the Engineering and Health Science fields that were considered non-STEM as they were terminal degrees not intended to be used to transfer and complete STEM bachelor’s degrees. Additionally, these degrees did not require advanced mathematics to be taken as part of the degree.

**Attrition.** Attrition was included as a dichotomous categorical variable with “no” and “yes” as the two possible outcomes. For the purpose of this study, attrition was defined as those who did not change to a non-STEM degree and did not graduate or transfer during the three-year time period. The purpose of measuring attrition was to capture students who suffered a negative outcome who were missed by the change of major to a non-STEM degree variable.

**Graduation and/or transfer.** Graduation and/or transfer was included as a dichotomous categorical variable. Students were defined as having graduated or transferred if a record existed of them graduating or transferring within three years of initial enrollment at the institution.
Gender. Gender was included as a dichotomous categorical variable with “female” and “male” being the two possible values - 55% (826) of the students were male while 45% (685) were female.

Socioeconomic status. Socioeconomic status (SES) was included as a dichotomous categorical variable - “lower SES” and “higher SES.” Students were classified as having a “lower SES” if they received a Federal Pell grant (Federal Student Aid, 2018) and/or a grant from New York State’s Tuition Assistance Program (TAP) (New York State Higher Education Services Corporation, 2018). Slightly over half of the students were categorized as “lower SES” (n=789, 52%).

Underrepresented minorities in STEM (URMS). URMS was included as a dichotomous categorical variable. Students who self-reported as Black, Hispanic, Native American, or Hawaiian were included in the “URMS” category while those reported as White or Asian were included in the other category. Students who did not report their ethnicities were reported as being biracial, or as a non-resident alien were excluded from the sample. Slightly less than half of the students (n=704, 47%) were URMS.

Analytical framework.

Transcript analysis. Transcript analysis allows the disaggregation of outcomes according to student group allowing for a rich analysis as they do not rely on memory and candor the way interviews do (Adelman, 1999; Bragg, 2017). For many community college students, academic coursework is the only connection they have to the institution which makes transcript analysis particularly insightful (Hagedorn & Kress, 2008). Transcript analysis is of particular use in this context since it provided an objective lens to explore factors that impacted graduation and transfer, degree change, attrition rates, and factors that impact science performance and credit production rates. Deidentified student transcript data were examined and the following variables were coded: semester of initial enrollment, part-time versus full-time status in initial semester only, every course taken by the student at the institution studied, associated grade and the amount of credits each course was worth, initial major, any change of major the student experienced, whether the student received a Pell or TAP grant, gender, and ethnicity. Transcripts provide reliable, institutionally verified maps of the student’s academic experience, including successful degree completion and/or transfer status (Hagedorn & Kress, 2008).

Statistical analyses. Descriptive statistics were generated to report student characteristics, course enrollments, and performance outcomes. Binary logistic regression was used as one inferential statistical method to compare contributing independent variables to categorical dependent outcomes after three years: students who successfully graduated or transferred vs. those who did not, students who persisted in STEM majors vs. degree changers to non-STEM fields, and students who persisted in college vs. those who suffered attrition. Binary logistic regression predicts which category a student is most likely to belong potentially identifying factors linked to students at risk of negative outcomes (for example, Cohen & Kelly, 2019a; Porchea et al., 2010). However, regression models are often limited due to omitted variables (Mood, 2010).

Multiple linear regression was used as a second inferential statistical method to identify which academic and demographic variables were significantly connected to science performance
and credit production rate. This method is capable of determining whether a significant relationship exists between a continuous dependent variable and multiple predictor variables which can be either continuous or categorical, as long as each categorical variable is dichotomous. Similar to logistic regression, multiple linear regression is limited to potentially significant predictors not included in the model (Field, 2013). For all regression models, variance inflation factor (VIF) values were below 2.4, indicating acceptable levels of correlation (Belsey et al., 1980).

The dependent variables chosen for this study were focused on the role that mathematics course taking has on persistence in STEM degrees, persistence in college, graduation or transfer rates, science performance, and credit production rates since these have significant potential to inform policy makers about how to improve STEM outcomes for community college students. The null hypotheses related to the prediction of student outcomes were the following:

1. Initial mathematics enrollment and performance does not predict degree change to a non-STEM discipline when combined in a multivariable model with the independent variables of student ethnicity, gender, and socioeconomic status.

2. Initial mathematics enrollment and performance does not predict graduation and transfer rates when combined in a multivariable model with the independent variables of student ethnicity, gender, and socioeconomic status.

3. Initial mathematics enrollment and performance does not predict attrition from college when combined in a multivariable model with the independent variables of student ethnicity, gender, and socioeconomic status.

4. Initial mathematics enrollment and performance does not predict degree science performance when combined in a multivariable model with the independent variables of student ethnicity, gender, and socioeconomic status.

5. Initial mathematics enrollment and performance does not predict credit production when combined in a multivariable model with the independent variables of student ethnicity, gender, and socioeconomic status.

IBM SPSS Statistics version 25 was used to calculate both descriptive and inferential statistics.

4.5 Results

Descriptive statistics on mathematics coursetaking, performance, and degree change.

Mathematics coursetaking. A large percentage of students began their STEM degrees unprepared to enroll in advanced mathematics. Only 19% of students started with advanced mathematics compared to 25% of students who began in developmental mathematics (Table 14); 21% of students began with a different mathematics course not designed to complete a degree requirement or prepare them for advanced mathematics (Statistics and Logic were the two most common courses). Of all students who began with developmental mathematics, only 26% continued on to algebra & trigonometry, and only 7% of the original sample ultimately ended up taking advanced mathematics. Of the 35% of students who began with algebra & trigonometry
ultimately took advanced mathematics, a larger percentage of students (57%) took advanced mathematics.

Table 14

Courses Taken for Initial Mathematics Enrollment

<table>
<thead>
<tr>
<th>Started with</th>
<th>Progressed to algebra &amp; trigonometry within 3 years (n)</th>
<th>%</th>
<th>Progressed to advanced mathematics within 3 years (n)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>developmental mathematics (n)</td>
<td>380</td>
<td>25%</td>
<td>99</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>7%</td>
</tr>
<tr>
<td>Started with algebra &amp; trigonometry (n)</td>
<td>532</td>
<td>35%</td>
<td>301</td>
<td>57%</td>
</tr>
<tr>
<td>Started with advanced mathematics (n)</td>
<td>279</td>
<td>19%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Prevalence of unsatisfactory mathematics performance.** The “DFW rate” (grade of D, F, or withdraw) has been used to identify high-risk courses that could serve as roadblocks to student success (Hossler et al., 2001). In developmental courses, grades of satisfactory (S) and unsatisfactory (U) were issued. A grade of unsatisfactory was the equivalent of a D, F, or W, as it indicated the student could not advance to the next developmental level or a credit-bearing course. Therefore, the “DFWU rate” (grade of D, F, withdraw, or unsatisfactory) was calculated and disaggregated according to initial enrollment in mathematics. Developmental courses had the lowest DFWU rate, however, students who initially enrolled in those courses had the highest DFWU rate in algebra & trigonometry (64%) and advanced mathematics (58%). Students who initially enrolled in algebra & trigonometry experienced far lower DFWU rates in that course (39%) compared to those who started in developmental mathematics, but had nearly the same DFWU rate in advanced mathematics (56%). Students who arrived at the institution qualified to take advanced mathematics experienced higher rates of success in advanced mathematics with a DFWU rate of only 38%.

**Degree change and graduation and/or transfer rates based upon initial mathematics enrollment.** Students who entered college qualified to take advanced mathematics experienced a higher rate of graduation and/or transfer than those who did not. Students who initially enrolled in advanced mathematics were more likely to persist in their STEM degrees than those who did not; 29% of these students changed to non-STEM degrees versus 52% of those who started with algebra & trigonometry and 47% for students who initially enrolled in developmental mathematics. Likewise, students who initially enrolled in advanced mathematics experienced a higher three-year graduation or transfer rate (48%) compared to students who initially enrolled in algebra & trigonometry (22%) and students who initially enrolled in developmental mathematics (12%) (Table 15).
Attrition rates based upon initial mathematics enrollment. As indicated above, students who initially enrolled in developmental mathematics or algebra & trigonometry changed to non-STEM majors at a higher rate than those who initially enrolled in advanced mathematics. However, not all who persisted in STEM degrees experienced positive outcomes. Students who initially enrolled in advanced mathematics experienced lower rates of attrition (31%) compared to those who initially enrolled in algebra & trigonometry (55%) and those who initially enrolled in developmental mathematics (78%) (Table 15).

Credit production rate based upon initial mathematics enrollment. Students who initially enrolled in higher levels of mathematics successfully completed credits at a higher rate than those who initially enrolled in a lower level of mathematics. Students who enrolled in developmental mathematics on average successfully completed 43% of the credits attempted, while those who initially enrolled in algebra and trigonometry completed 72% of the credits attempted, and students who initially enrolled in advanced mathematics had a credit production rate of 81% (Table 15).

Science performance based upon initial mathematics enrollment. Students who initially enrolled in higher levels of mathematics had higher achievement in their science courses than those who initially enrolled in a lower level of mathematics. Students who enrolled in developmental mathematics on average had a GPA of 1.44 in their science courses, while those who initially enrolled in algebra and trigonometry earned a GPA of 2.05 in their science coursework, and students who initially enrolled in advanced mathematics had a science GPA of 2.65 (Table 15).

Multivariable models predicting STEM persistence.

Predictors of change of major to non-STEM. A logistic regression model was generated to test the null hypothesis that initial enrollment in mathematics, performance in mathematics, and student demographics, including gender, socioeconomic status, and ethnicity, did not predict change of major to a non-STEM discipline (Table 16). The Pearson chi-square value (χ² =

<table>
<thead>
<tr>
<th>Initial Mathematics Enrollment</th>
<th>Changed to Non-STEM Major n (%)</th>
<th>Attrition n (%)</th>
<th>Credit Production Rate (%)</th>
<th>Science GPA</th>
<th>Graduated or Transferred without Changing Degree n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developmental Mathematics</td>
<td>179 (47%)</td>
<td>156 (78%)</td>
<td>43%</td>
<td>1.44</td>
<td>45 (12%)</td>
</tr>
<tr>
<td>Algebra &amp; Trigonometry</td>
<td>275 (52%)</td>
<td>141 (55%)</td>
<td>72%</td>
<td>2.05</td>
<td>116 (22%)</td>
</tr>
<tr>
<td>Advanced Mathematics</td>
<td>82 (29%)</td>
<td>62 (31%)</td>
<td>81%</td>
<td>2.65</td>
<td>135 (48%)</td>
</tr>
</tbody>
</table>

Table 15
Outcomes Based Upon Initial Mathematics Enrollment
1350.604, \( p < .001 \) indicated the logistic model fit the data well, predicting 59.1% of the cases. The model indicated that initial enrollment in mathematics, performance in mathematics, and gender were significant predictors of degree change thereby rejecting the null hypothesis, however, SES and ethnicity were shown not to be significant predictors of degree change. The odds ratio, \( \exp(\beta) \), for starting with developmental mathematics was 0.697, indicating that students who started with developmental mathematics were 43% more likely to change to a non-STEM degree. Students who first enrolled in algebra & trigonometry were nearly four times more likely to change their degrees than students who started with advanced mathematics, as indicated by the odds ratio of 0.268. Interestingly, the model indicated that each one-point increase in a student’s mathematics GPA resulted in a 12% increase in likelihood that students changed to non-STEM majors (\( \exp(\beta) = 1.122 \)). The odds ratio for gender was 1.351 indicating that men were 35% more likely to change their degree than women. The Nagelkerke \( R^2 \) value for the model was 0.087, indicating a small to medium effect size (Field, 2013).

Table 16

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \beta )</th>
<th>S.E.</th>
<th>Wald</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Started w/Dev MAT</td>
<td>-0.361</td>
<td>0.171</td>
<td>4.467**</td>
<td>0.697</td>
<td>0.498 - 0.974</td>
</tr>
<tr>
<td>*Started w/Algebra &amp; Trig.</td>
<td>-1.315</td>
<td>0.202</td>
<td>42.183***</td>
<td>0.268</td>
<td>0.181 - 0.399</td>
</tr>
<tr>
<td>Math GPA</td>
<td>0.115</td>
<td>0.057</td>
<td>4.104**</td>
<td>1.122</td>
<td>1.004 - 1.254</td>
</tr>
<tr>
<td>Gender</td>
<td>0.301</td>
<td>0.132</td>
<td>5.207**</td>
<td>1.351</td>
<td>1.043 - 1.750</td>
</tr>
<tr>
<td>URMS</td>
<td>-0.190</td>
<td>0.134</td>
<td>2.002</td>
<td>0.827</td>
<td>0.636 - 1.076</td>
</tr>
<tr>
<td>SES</td>
<td>-0.006</td>
<td>0.133</td>
<td>0.002</td>
<td>0.994</td>
<td>0.766 - 1.290</td>
</tr>
</tbody>
</table>

*Adv MAT is the reference category

**\( p \leq .05 \), ***\( p \leq .001 \)

Predictors of graduation/transfer rates. A logistic regression model was generated to test the null hypothesis that the initial enrollment in mathematics, performance in mathematics, and student demographics, including gender, socioeconomic status, and ethnicity, did not predict graduation or transfer rates (Table 17). The Pearson chi-square value (\( \chi^2 = 157.113, \ p < .001 \)) indicated the logistic model fit the data well, predicting 75.5% of the cases. The logistic model indicated that initial enrollment in mathematics, performance in mathematics, and ethnicity were significant predictors of degree change thereby rejecting the null hypothesis, however, gender and SES were not shown to be predictors of degree change. The odds ratio for starting with developmental mathematics was 0.173, indicating that students who started with developmental mathematics were nearly six times less likely to graduate or transfer. Starting with algebra & trigonometry, the odds ratio of 0.315 indicated that students were just over three times less likely to graduate or transfer than students who started with advanced mathematics. Additionally, the model indicated that each one-point increase in a student’s mathematics GPA resulted in a 61% increase in likelihood that students graduated or transferred (\( \exp(\beta) = 1.612 \)). The odds ratio for ethnicity was 1.382 indicating that URMS were 38% more likely to graduate or transfer than non-URMS. The Nagelkerke \( R^2 \) value for the model was 0.207, indicating a medium effect size.
Table 17
Logistic Regression Model Predicting Graduation and/or Transfer Rates

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>S.E.</th>
<th>Wald</th>
<th>Odds Ratio $\exp(\beta)$</th>
<th>95% Confidence Interval For Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Started w/ Dev MAT</td>
<td>-1.754</td>
<td>0.260</td>
<td>45.681***</td>
<td>0.173</td>
<td>0.104 - 0.288</td>
</tr>
<tr>
<td>*Started w/ Algebra &amp; Trig.</td>
<td>-1.154</td>
<td>0.166</td>
<td>48.408***</td>
<td>0.315</td>
<td>0.228 - 0.437</td>
</tr>
<tr>
<td>MAT GPA</td>
<td>0.478</td>
<td>0.070</td>
<td>47.072***</td>
<td>1.612</td>
<td>1.407 - 1.848</td>
</tr>
<tr>
<td>Gender</td>
<td>0.256</td>
<td>0.157</td>
<td>2.663</td>
<td>1.292</td>
<td>0.950 - 1.756</td>
</tr>
<tr>
<td>URMS</td>
<td>0.323</td>
<td>0.161</td>
<td>4.043**</td>
<td>1.382</td>
<td>1.008 - 1.894</td>
</tr>
<tr>
<td>SES</td>
<td>0.022</td>
<td>0.157</td>
<td>0.020</td>
<td>1.023</td>
<td>0.752 - 1.391</td>
</tr>
</tbody>
</table>

*Adv MAT is the reference category
**$p < .05$, ***$p < .001$

Predictors of attrition rates. A logistic regression model was generated to test the null hypothesis that the initial enrollment in mathematics, performance in mathematics, and student demographics, including gender, SES, and ethnicity, did not predict attrition rates (Table 18). The Pearson chi-square value ($\chi^2 = 159.519, p < .001$) indicated the logistic model fit the data well, predicting 71.2% of the cases. The logistic model indicated that initial enrollment in mathematics, performance in mathematics, and gender were significant predictors of degree change thereby rejecting the null hypothesis, however, SES and ethnicity were shown to not be significant predictors of degree change. The odds ratio for matriculating in developmental mathematics was 4.14, indicating that students who started with developmental mathematics were over four times more likely to experience attrition than those who started with advanced mathematics. Starting with algebra & trigonometry, the odds ratio of 2.94 indicated that students were nearly three times more likely to experience attrition than students who started with advanced mathematics. Additionally, the model indicated that each one-point increase in a student’s mathematics GPA made them less than half as likely to experience attrition ($\exp(\beta) = 0.442$). The odds ratio for gender was 0.417 indicating that males were less than half as likely to experience attrition than females. The Nagelkerke $R^2$ value for the model was 0.344, indicating a large effect size.

Table 18
Logistic Regression Model Predicting Attrition

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>S.E.</th>
<th>Wald</th>
<th>Odds Ratio $\exp(\beta)$</th>
<th>95% Confidence Interval For Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Started w/Dev MAT</td>
<td>1.421</td>
<td>0.334</td>
<td>18.058**</td>
<td>4.140</td>
<td>2.150 - 7.971</td>
</tr>
<tr>
<td>*Started w/Algebra &amp; Trig.</td>
<td>1.079</td>
<td>0.227</td>
<td>22.616**</td>
<td>2.941</td>
<td>1.885 - 4.588</td>
</tr>
<tr>
<td>Math GPA</td>
<td>-0.817</td>
<td>0.093</td>
<td>76.520**</td>
<td>0.442</td>
<td>0.368 - 0.531</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.874</td>
<td>0.218</td>
<td>16.122**</td>
<td>0.417</td>
<td>0.272 - 0.639</td>
</tr>
<tr>
<td>URMS</td>
<td>-0.248</td>
<td>0.211</td>
<td>1.382</td>
<td>0.780</td>
<td>0.516 - 1.180</td>
</tr>
<tr>
<td>SES</td>
<td>-0.074</td>
<td>0.207</td>
<td>0.126</td>
<td>0.929</td>
<td>0.620 - 1.393</td>
</tr>
</tbody>
</table>

*Adv MAT is the reference category
**$p < .05$
Predictors of science performance. A multiple linear regression was performed to predict science performance based on initial enrollment in mathematics, performance in mathematics, and student demographics, including gender, socioeconomic status, and ethnicity. Several significant factors were identified in the regression equation \( F(7, 1049.496)=76.712, p < .001 \); \( R^2 = 0.332 \), indicating a large effect size. Science performance is equal to \( 0.862 + 0.223(\text{started with algebra and trigonometry}) + 0.695(\text{started with advanced mathematics}) + 0.524(\text{mathematics performance}) - 0.144(\text{SES}) \), where started with algebra and trigonometry was coded as 0 = no, 1 = yes, started with advanced mathematics was coded as 0 = no, 1 = yes, mathematics performance was measured in quality points, and SES was coded as 0 = lower and 1 = higher. Science performance increased 0.223 quality points for students who began with algebra and trigonometry versus those who did not, 0.695 quality points for students who began with advanced mathematics versus those who did not, 0.524 quality points for each quality point increase in mathematics performance, and decreased 0.144 quality points for students in a lower SES. Initial enrollment in algebra and trigonometry, initial enrollment in advanced mathematics, mathematics performance, and SES were significant predictors of science performance whereas gender and ethnicity were not.

Predictors of credit production rate. A multiple linear regression was calculated to predict credit production based on initial enrollment in mathematics, performance in mathematics, and student demographics, including gender, socioeconomic status, and ethnicity. A significant regression equation was found \( F(7, 38.000)=76.712, p < .001 \); \( R^2 = 0.488 \), indicating large effect size. Credit production rate is equal to \( 0.437 - 0.040(\text{started with developmental mathematics}) + 0.053(\text{started with algebra and trigonometry}) + 0.106(\text{started with advanced mathematics}) + 0.128(\text{mathematics performance}) \) where started with developmental math was coded as 0 = no, 1 = yes, started with algebra and trigonometry was coded as 0 = no, 1 = yes, started with advanced mathematics was coded as 0 = no, 1 = yes, and mathematics performance was measured in quality points. Credit production rate decreased 4% students for students who began with developmental math versus those who did not, increased 5% for students who began with algebra and trigonometry versus those who did not, increased 11% for students who began with advanced mathematics versus those who did not, and increased 13% for each quality point increase in mathematics performance. Initial enrollment in developmental mathematics, initial enrollment in algebra and trigonometry, initial enrollment in advanced mathematics, and mathematics performance were significant predictors of science performance whereas all student demographic variables were not.

4.6 Limitations

This study had several limitations. Causation was unable to be determined as the study was correlational by design and not randomized and controlled. The results indicated a relationship between the initial enrollment in mathematics and students changing to non-STEM degrees and attrition but not that the initial mathematics enrollment was the cause of those relationships. This study may not be generalizable since the data originated from a single community college in a suburban setting. Although transcripts provided data for a robust analysis, it was not able to explore fully the complexities of attrition and persistence; transcript analysis was unable to determine why students made the academic decisions they did or determine why they achieved at the levels they did (Hagedorn & Kress, 2008). DFWU rates also cannot determine why students failed to earn a transferrable grade in a course; outside influences including family
responsibilities or financial stress might have been contributing factors to the results found. Future research is needed to explore the student-level motivations that led to change of major and attrition. The data studied also lacked instructor variables, including pedagogical strategies and grade distributions. The data also lacked pre-college transcript information, limiting determination of high school preparedness other than placement test scores, which may not have been truly representative of student ability. A more nuanced interpretation of the results may have been possible if the study were able to examine differences in teaching style and different measures of student preparation.

4.7 Discussion

The present study applied deconstructive analysis (Bahr, 2013) in exploring the influence of contextual variables and academic processes on the outcomes of several cohorts of community college students. Prior research on measures of community college success has highlighted the need to examine the dynamic nature of students’ academic intentions throughout matriculation (Bailey et al., 2005; Calzagno et al., 2007). Academic persistence may be influenced by self-efficacy formed through achievement of academic milestones that lead to desired career pathways (Bandura, 1986). For students majoring in science and related disciplines, gateway coursework in mathematics often influences outcomes expectations and behavioral persistence (Lent et al., 1991; Lopez et al., 1997). Although community college student attrition from remedial sequences has been explored in general terms (Bahr, 2012; Calzagno et al., 2007), this study builds upon prior work in the filed by exploring mathematics enrollment and achievement as they relate specifically to STEM persistence. This study also explored student background variables as predictors, including measures of socioeconomic status which have often been excluded in previous studies. These findings reveal significant relationships between developmental mathematics coursetaking and performance and several important academic dependent variables, suggesting the need for vertical alignment of pre-college mathematics preparation with the knowledge and skills required for successful completion of two-year and four-year STEM degrees.

Although the majority of community college students in this study completed their developmental mathematics requirements, few progressed to algebra & trigonometry and even fewer attempted advanced mathematics; for those who did, a majority did not achieve a transferrable grade. Initial enrollment in algebra & trigonometry was likewise connected to several negative outcomes as a large percentage did not matriculate into advanced mathematics with less than half of those who did earning a transferrable grade. These results highlight the struggles faced by students who arrive at community college unprepared for advanced mathematics, and indicate a population in need of targeted mathematics interventions to prevent a talent drain out of STEM.

Initial enrollment in mathematics was a significant predictor of all academic outcomes, with students starting in the lowest level of mathematics significantly more likely to change to non-STEM degrees, less likely to graduate or transfer, more likely to suffer attrition, experience lower achievement in science, and achieve lower credit production rates. This suggests students in the developmental mathematics track require additional interventions to strengthen their potential for success in completing STEM degrees and advancing into the science and technological workforce. Performance in mathematics was also a significant predictor of most academic outcomes as students who earned more quality points were significantly more likely to graduate or transfer, less likely to suffer attrition, more likely to succeed in their science
coursework, and more likely to earn credits. Notably, students who performed better in mathematics were more likely to switch out of STEM. Since performance in mathematics included all mathematics courses taken and not only advanced mathematics, a possible explanation for this outcome was that students who switched out of STEM performed well in lower levels of mathematics and explored academic options that did not include advanced mathematics. Overall, these results suggest that academic factors related to mathematics coursetaking and performance may be more important in determining student STEM outcomes than demographic variables.

Demographic factors were significant predictors of several student outcomes, but there was no consistent factor that predicted all academic performance measures. Gender was a predictor for degree change out of STEM and attrition (men were more likely to switch out of STEM while women were more likely to suffer attrition), but was not a significant predictor of graduation or transfer rates, science performance, or credit production rate. Notably, ethnicity was a predictor for successful graduation or transfer, with URMS 38% more likely to reach these thresholds, but was not a significant predictor of degree change out of STEM, attrition, science performance, or credit production rate. This finding was consistent with prior research that suggested the disparate participation of URMS in STEM has been attributed to inadequate pre-college preparation; those with equivalent preparation tend to do as well as or outperform majority students (Tyson et al., 2007). This suggests that community colleges may be particularly effective in promoting diverse participation in STEM disciplines, both in terms of workforce readiness and four-year college enrollment. SES predicted performance in science but did not predict degree change out of STEM, graduation or transfer rates, attrition rates, or credit production rate. This finding was positive and further supports the importance of community colleges in facilitating equitable outcomes and socioeconomic mobility for students from less privileged backgrounds, contradicting prior research that suggested socioeconomic background is a persistent predictor of post-secondary STEM achievement (Xie, Fang, & Shauman, 2015).

4.8 Implications

Community colleges demonstrate the potential for increasing STEM participation of underrepresented populations but have not yet fully realized that goal (Wang, 2015). Although considerable literature exists that explores how demographic related variables relate to student outcomes (Bahr et al., 2017; Bailey et al., 2005; Bragg, 2017; Calcagno et al., 2007; Chen, 2013; Dika & D’Amico, 2016; Gayles & Ampaw, 2011; Maxwell et al., 2003; Wang, 2013), this study suggests that community colleges may narrow the STEM participation gap by focusing on preventative measures and fostering student resilience when faced with academic roadblocks. Even though students completed developmental mathematics at a reasonable rate, that academic achievement did not always translate to those students completing advanced levels of mathematics. This may indicate that the curriculum of developmental coursework is not adequate to prepare students for advanced mathematics and science coursework. The institution where this study took place recently overhauled their developmental mathematics curriculum, however, the overhaul introduced a new developmental course geared towards non-STEM majors and did not change the required course sequences for STEM majors. Algebra & trigonometry typically serves as the gateway to advanced mathematics (Bahr et al., 2017), but these results indicated that it was not an adequate preparatory course for advanced mathematics. Institutions may
improve outcomes for STEM majors by reconceptualizing their developmental curriculum to focus on the essential skills for advanced mathematics and science coursework.

Mathematics self-efficacy is a key to students choosing to pursue a STEM degree (Hackett & Betz, 1989; Lent et al., 1991; Lopez et al., 1997; Wang, 2013), while achievement in mathematics is central to completing a STEM degree (Wang, 2015). The results of this study showed that a majority of students entered the institution unprepared to take advanced mathematics and were largely unsuccessful in the mathematics coursework for which they matriculated. Experiencing difficulties in early mathematics coursework may harm a student’s self-efficacy thereby leading her to abandon a STEM degree. This is particularly worrisome if the courses associated with this outcome are not aligned with the skills required to be successful in advanced mathematics. Students may be further discouraged by failure in courses that do not even qualify for transfer to a four-year institution. Self-efficacy may be improved by providing clarity on transferable coursework and curriculum mapping to reach the achievements required for STEM careers and two- and four-year degrees.

Recent research has suggested the logistical complexities of navigating interdependent STEM requirements further exacerbates attrition and requires more targeted advisement and explicit, comprehensive institutional communications with students (Bahr et al., 2017; Deil-Amen, 2011). Structured degree pathways improve outcomes and advisement is critical for ensuring students progress through degree requirements (Bailey et al., 2015; Moore & Shulock, 2011; Rosenbaum et al., 2006; Scott-Clayton, 2011; Wang, 2016). However, many community colleges struggle to provide adequate and well-trained advisors to their students (Center for Community College Student Engagement, 2010; Packard et al., 2011). Committing more resources to hire additional advisors for STEM majors and/or providing training to existing advisors may help students navigate these pathways and improve outcomes. Multiple suggested pathways through STEM degree attainment should be made readily available and easily accessible to students to help those who do not have access to adequate academic advisement.

Attrition out of STEM may also be impacted by the lack of a community amongst first-year community college STEM majors. Community college STEM majors routinely find themselves dispersed across a variety of sections and courses, which may diminish the feeling of social integration and negatively impact outcomes (Maxwell et al., 2003). The designation of specific sections for first-year STEM majors may simplify the advisement and registration processes and help centralize students with similar interests and promote inter-STEM major socialization, which has been shown to facilitate the procedural agency for navigating course selection and academic success (Deil-Amen, 2011). The creation of a freshmen seminar for STEM majors may provide a mechanism to increase the feeling of academic and social relatedness and improve outcomes.

**Future research.** Additional large-scale studies may shed light upon generalizable patterns of community college student STEM pathways as they relate to mathematics enrollment and performance. Such studies could include randomized comparisons of students with declared STEM intentions and those in other fields, particularly as their experiences relate to mathematics remediation and performance. Qualitative research with a smaller, purposely selected sample may provide nuanced insights on how performance in science and mathematics courses impacts affective domains that often influence STEM persistence for community college students. Such studies may identify underlying motivations for migration out of STEM fields. Identifying supporting scaffolds and barriers to the success of community college students in STEM is
essential for developing educational policies and interventions for diverse and equitable participation in these disciplines.
References


