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Abstract: This study explored science, mathematics, and general academic factors that predicted outcomes for community college students ($N = 3052$) in a regional institution. A binary logistic regression was performed to deter-

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mine significant independent variables contributing to successful outcomes (graduation or transfer) vs. non-completion. Transcript data over three years revealed that 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.

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, Katsinas, & Hardy, 2010). Recent policy documents have also highlighted the value of community colleges in providing entry to STEM workforce development (National Academies of Sciences, Engineering, & Medicine [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; Hagedorn, Cabrera, & Prather, 2010; Lee & Frank, 1990; 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?

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 (American Association of Community Colleges [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 explores 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.

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; National Center for Education Statistics [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, Jenkins, & Leinbach, 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, Leinbach, & Jenkins, 2006). 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 (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 et al., 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 & Arm-

strong, 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 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 currently gaps in the literature that this research seeks to address.

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 taking the sum of the products of numerical grade and number of credits for each course, and dividing 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 coursetaking 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.

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.

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).

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

TABLE 1.
SUCCESS RATE BASED UPON SCIENCE AND MATHEMATICS COURSETAKING

	Total Students	*Successful Outcome (n)*	*Graduation and/or Transfer (%)*
Did Not Take Science	1076	246	23
Took at Least 1 Science	1976	1193	60
Did Not Take Math	314	77	25
Took at Least 1 Math	2738	1362	50
Did Not Take Science or Math	223	51	23
Took at Least 1 Science AND 1 Math	1885	1167	62

TABLE 2.
ACADEMIC PERFORMANCE MEASURES BASED UPON SCIENCE AND MATHEMATICS COURSETAKING

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

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 then 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 then mathematics GPA, and science and mathematics GPAs were statistically lower than GPAs in other academic courses.

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

Table 3.
Descriptive Academic Statistics of Student Groups Based Upon Outcomes (N =3052)

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

the logistic model were statistically significant. All six of the variables were significant predictors, as indicated in Table 4.

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 ($c^2 = 427$, $p < 0.001$) 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(β), 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 reme-

TABLE 4.
LIKELIHOOD RATIO TESTS FOR INCLUSION OF INDEPENDENT VARIABLES IN LOGISTIC MODEL

Academic Variables	*Likelihood Ratio Tests*		
	c^2	*df*	*Significance*
1. Math Remediation Required	71.369	1	.000***
2. English Remediation Required	4.516	1	.034*
3. Successful Completion Rate of SCI Courses	219.448	1	.000***
4. Number of SCI Courses Taken	25.711	1	.000***
5. Successful Completion Rate of MAT Courses	91.568	1	.000***
6. Number of MAT Courses Taken	14.467	1	.000***

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

diation 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.

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

Table 5.
Logistic Regression Model of Student Groups Based Upon Outcomes

	b (SE)	*Wald*	*Odds Ratio exp(b)*	*95% Confidence Interval for Odds Ratio*	
				Lower	*Upper*
Math Remediation Not Required	0.654*** (0.120)	29.696	1.924	1.521	2.435
English Remediation Not Required	0.273* (0.122)	5.021	1.314	1.035	1.669
Completion Rate of Science Courses	1.475*** (0.157)	88.203	4.370	3.212	5.945
Number of Science Courses Taken	0.100** (0.033	8.926	1.105	1.035	1.180
Completion Rate of Math Courses	1.780*** (0.184)	94.059	5.932	4.140	8.502
Number of Math Courses Taken	0.143*** (0.040)	13.068	1.154	1.068	1.247

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

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 develop-

ment 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 withdrawal 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.

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.

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