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Academic and Social Integration Variables Influencing the Success of Community College Transfer Students in Undergraduate Engineering Programs

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Academic and social integration variables influencing the success of community college transfer students in undergraduate engineering programs

by

Marcia Rae Rector Laugerman

A dissertation submitted to the graduate faculty in partial fulfillment of the requirements for

the degree of

DOCTOR OF PHILOSOPHY

Major: Industrial and Agricultural Technology

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2012

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DEDICATION

This work is dedicated to:

My parents;

Doris Ann Sharer Rector and Ben Kirby Rector

My legacy;

Steven, James and Deanna Laugerman

And my destiny;

The Lord Jesus Christ who with his blood purchased my inheritance in heaven

“For the reverence and fear of God are basic to all wisdom. Knowing God results in every kind of understanding.” The Living Bible, Proverbs 9:10

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Steve Mickelson, Visionary, Advocate, Mentor and Strengths Finder

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ABSTRACT

The goal of this dissertation is to collect and analyze data to determine success strategies for community college (CC) transfers to engineering. It does so by analyzing transcript level data collected longitudinally over a 10-year period as community college transfer students' progress before and after transfer into an engineering program. Characteristics of successful students are identified in terms of the academic and social integration variables using descriptive and inferential statistics. In addition to providing data analysis, the results determine distinctive strategies to increase the success of community college transfers in engineering.

The research was funded by the National Science Foundation (NSF) Science Technology Engineering and Mathematics (STEM) Talent Expansion Program initiative. Recognizing the importance of increasing the number of graduates in STEM fields, the NSF has funded the STEM Talent Expansion Program (STEP). This research discovers high-influence academic variables that a CC transfer student can use to aid in successfully pursuing an engineering degree. This research makes a strong case that even small increases in GPA have significant effects on increasing the graduation rates in engineering. A notable finding is the recommended thresholds of success for the academic variables.

This study finds that for CC transfer students to have the best chances of graduating with an engineering degree, they need to adopt the social integration strategies offered at the CC, join a learning community at the university, and focus on being successful in the core engineering courses, either at the CC or at the university.

CHAPTER 1. GENERAL INTRODUCTION AND LITERATURE REVIEW

Introduction

The global marketplace is characterized by dependence on knowledge in science and technology, yet the percentage of Americans who receive degrees in science, technology, engineering, and mathematics (STEM) is estimated at less than 16% of the total bachelors degree's awarded. This is substantially less than that of China (47%), South Korea (38%), and Germany (28%) (National Science Board, 2010). At the same time, the demand for STEM workers is growing faster than the supply (Increasing the Number of STEM Graduates, 2010). Additionally, more than half of all students enrolling in STEM disciplines change to non-STEM majors before graduation, and the exodus among women and underrepresented minorities is particularly acute (National Center for Education Statistics, 2009).

Even today, despite current economic conditions, shortages of STEM workers exist. Projections indicate that STEM employment needs will continue to grow as much as 17% over the next ten years (Meeting the STEM Workforce Challenge, 2011). Most of these STEM-related jobs require a college degree or higher. This study examines variables which are believed to promote more STEM graduates, specifically in the field of engineering.

Reversing the current trend may be many years away because of the lead time required for mathematics preparation. The students graduating in 2012 decided to take their mathematics preparation courses as far back as middle school. The students making that same decision today won't complete advanced training for science and engineering

occupations until the year 2022 or later, depending on how much time it takes them to complete a degree.

This warning was issued by the National Academy of Engineering in 2005: “If action is not taken now to change these trends, we could reach 2020 and find that the ability of U.S. research and educational institutions to regenerate has been damaged and that their preeminence has been lost to other areas of the world” (National Research Council, 2005, p. 31).

Leaders in STEM fields have called for major initiatives to address these trends (The National Academies Press, 2007; National Science Board, 2006 & 2007). In engineering, this need for change has been highlighted by the American Society for Engineering Education (ASEE), the National Research Council (NRC), the National Academy of Engineering (NAE), and the National Science Foundation (NSF).

The National Academy of Engineering, National Academy of Sciences, and Institute of Medicine (The National Academies Press, 2007) published *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, which issued a strong warning that America’s technological advantages were eroding. In 2010, the same groups published, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (The National Academies Press, 2010), to indicate that the problem was increasing in intensity rather than improving.

Another groundbreaking book, *Enhancing Community College Pathways to Engineering Careers*, from the National Academy of Engineering and the Engineering Research Council (National Research Council, 2005), endorsed the community college (CC)

pathway to an engineering career, but noted that students often faced obstacles on this pathway.

This report concluded: “Accessible, reliable data about student and institutional outcomes would make it possible to prioritize and address many of the problems outlined in this report. Currently, however, not enough data are available on CC student educational outcomes and pathways to success. Institutions report that they do not have the funds to collect and analyze data on students” (National Research Council, 2005, p. 67). “Most often, community colleges lose sight of students once they transfer to four-year institutions, precisely when they should begin tracking their educational and career trajectories. Compiling and publicizing data on transfer students’ success in obtaining B.S. engineering degrees would demonstrate the effectiveness of engineering studies in community colleges and improve their recruitment rates” (National Research Council, 2005, Executive Summary, p. 5).

As the United States seeks to graduate more engineers and scientists, CCs are emerging as a vital source of students. In the past three years, more than 1.4 million additional U.S. students turned to CCs for their post-secondary education, bringing the Fall 2011 total CC enrollment to 8.2 million (Baime, 2011). According to 2011 data from the American Association of Community Colleges (AACC), it is estimated that CCs now educate about 44% of all undergraduates in the United States at some time during their college career. This number is expected to grow. Between 2007 and 2009 the number of full-time students enrolled in CCs grew 24% (Mullin, 2011).

The CC mission of open enrollment and equal opportunity for education is consistent with the mission and vision of education in the United States (Baime, 2011). Community

college leaders believe that providing a more level institutional playing field is consistent with the federal government's traditional role in ensuring equality of opportunity in higher education (Baime, 2011). Community colleges bring education closer to Americans through both distance and diversity. Most are within driving distance (AACC, 2009). Furthermore, open-enrollment policies offer equal opportunity to obtain an education. Community colleges also provide educational opportunity for students of diverse backgrounds. Of the eight million CC students currently enrolled in for-credit courses, 42% are the first in their family to attend college, 46% are receiving financial aid, and 45% are from an underrepresented ethnic minority group (AACC, 2011). Moreover, students from underserved groups, especially Hispanics and Native Americans, traditionally have enrolled in CCs in greater numbers than in public four-year institutions. These relative proportions are likely to increase since the population of students from underrepresented ethnic groups is expected to increase substantially in the coming decades (AACC, 2011).

In addition, CCs are a cost-effective means of advancing career skills, obtaining an associate's degree, or working toward a bachelor's degree. According to data compiled by the College Board and the American Association of Community Colleges, tuition and fees at CCs on average are only 36.2% of the mean four-year public college tuition and fee bill (AACC, 2009). For students pursuing a bachelor's degree, starting at a CC can save thousands of dollars over the costs of starting at a 4-year public university, thus minimizing debt load.

Community college graduates also have a positive impact on the local and state economy. Students from CCs who complete bachelor's degrees may be more likely to stay in-state once they have finished their education, especially in high-demand fields such as

engineering. A recent study at Iowa State University (Laugerman & Mickelson, 2011), found that a significantly higher percentage of engineering graduates who transferred from a CC took jobs in-state as compared to non-transfer students.

This growing need for CC services has come at a time of financial stress. With few exceptions, CCs have endured cuts in both state and local support which greatly supplement tuition income. According to a recent Delta Cost Report on college spending trends (2011), CCs have endured cuts in the state and local support that account for about 55% of their revenue (Baime, 2011). In addition, the educational effectiveness of CCs is under new scrutiny as a result of accountability required by the Student Right-to-Know and Campus Security Act of 1990, combined with a greater competition for the state funds traditionally directed to the colleges (Delta Cost Report, 2011).

Despite all this, there has been surprisingly little rigorous research on institutional effectiveness in CCs (Bailey, Jenkins, & Leinbach, 2005). In addition, little data are available about CC transfers from the university perspective (Handel, 2007). As CCs increasingly rely on data to inform institutional decisions about best practices, longitudinal data are needed to assess students' progress through educational institutions. However, assessing student level data is dependent on data structures, policies, and practices that are difficult to coordinate between CCs and universities (Mullin, 2011).

The aim of this dissertation is to collect and analyze data to determine success strategies for CC transfers to engineering. This research addresses a gap in previous work by measuring longitudinal data for CC students as they progress through the university both before and after transfer into an engineering program. In addition to providing data analysis,

the results will determine targeted strategies to increase the success of CC transfers in engineering.

The results reported in this dissertation add to the overall body of research promoting more STEM graduates, specifically in engineering (Increasing the Number of STEM Graduates, 2010). It does so by addressing retention in engineering for CC transfer students and in some cases comparing these rates to those for students who enter the College of Engineering directly from high school.

The focus of the research is to evaluate both academic and social integration variables contributing to student success so as to increase programming effects on retention. This makes use of Tinto's interactionist theory (Tinto, 1993), which broadly defines academic integration as doing well in courses and social integration as social relationships with other students and faculty. In this research social integration is defined as cooperation-based strategies that increase connections between the CC and the university. Social integration will be measured by connection-based variables that maximize success for the CC transfers to engineering. These include an integrated program of learning communities, engineering orientation offered at the CC, an engineering admissions partnership program, and learning communities specifically for transfer students offered at the university.

Academic integration is defined as the ability to achieve satisfactory grades in core-engineering-Basic Program (BP) courses as a whole, and specific achievement levels necessary in Calculus I, Calculus II, and Physics I. These courses have been identified as important measures of student success in engineering (Budny et al., 1998; Levin & Wyckoff, 1990). This study diverges from previous research in that the social and academic integration variables will be measured both at the CC and at the university. It will use statistical methods

to determine successful social and academic integration variables that maximize success rates in engineering.

Persistence in engineering is historically bound to performance in core-engineering courses, which include: Calculus I, Calculus II, and Physics I (Budny et al., 1998; Levin & Wyckoff, 1990). If one were to know the level of success needed in difficult-to-pass core-engineering courses, then students and advisors could pinpoint achievement levels necessary before proceeding. This information would also be beneficial to know when a student should transfer to increase the likelihood of success. This research study examines the achievement necessary in the core engineering courses—the BP—to promote success in engineering for CC transfer students. The goal of this study is to gain a better understanding of the dynamics of persistence when transfer engineering students encounter the difficult-to-pass BP courses.

Literature Review

National Initiatives to Increase STEM Graduates

Since identifying a crisis in the area of global technological competitiveness and the low numbers of STEM graduates, the National Science Foundation (NSF) has been one of the biggest funders of undergraduate research in STEM fields. In addition to the Science Technology Engineering and Mathematics (STEM) Talent Expansion Program (STEP), the MentorLinks program, supported by NSF and managed by the American Association of Community Colleges (AACC), gives CCs the opportunity to start up needed programs in STEM fields with the assistance of an experienced mentor (Mentor Links Program, 2011). Additionally, the League for Innovation in the Community College and the National Institute for the Study of Transfer Students convene annual conferences to help advance student success in STEM fields.

Many other federal agencies also fund undergraduate research in STEM fields. These include the bigger players like the Department of Education (DOE), the National Institutes of Health (NIH), and others like the National Aeronautics and Space Administration (NASA), the National Institute of Standards Technology (NIST), and National Oceanic and Atmospheric Administration (NOAA). Many of the agencies concentrate on undergraduate research experiences and the development of STEM students through to the PhD degree.

Other national initiatives have been launched specifically to increase the success of CC transfer students. The National Articulation and Transfer Network (NATN)—a national research and policy development resource for students, counselors, administrators, researchers, and policymakers—offers an up-to-date repository of state articulation policies and other key information on transfer issues. NATN member organizations are a growing coalition of CCs and baccalaureate-granting institutions that work together to place students on pathways to opportunities that lead to advancement and success in higher education (National Articulation and Transfer Network, (2011).

In 2004, the Lumina Foundation for Education launched “Achieving the Dream: Community Colleges Count,” a national initiative aimed at improving success among CC students, particularly for low-income students and students of color. Now encompassing more than 130 institutions in 24 states and the District of Columbia, Achieving the Dream helps CCs build a “culture of evidence” by using student records and other data to examine students’ performance over time and to identify barriers to academic progress (Lumina Foundation, 2011). From there, CCs are expected to develop intervention strategies designed to improve student outcomes, conduct further research on student progress, and bring effective programs to scale. As a result, it is anticipated that colleges will see measurable

improvements over time in student outcomes, including increased progress through developmental education and college-level “gatekeeper” (introductory) courses, grades, persistence, and completion of credentials (Lumina Foundation, 2011).

Challenges for Community Colleges

The growing need for CC services has come at a time when many institutions have endured cuts in both state and local support (Delta Cost Report, 2011). At the same time, they have fewer resources to draw upon to meet these cuts than other types of institutions. Comparing costs on a per-student basis, CCs spend less than half of expenditures at public research institutions, according to the latest Delta Cost Report (2011) on college spending trends. The per-student spending shrank by 3.4% from 2008 to 2009, a higher rate than for other higher education sectors (Delta Cost Report, 2011).

In addition, the educational effectiveness of CCs is under new scrutiny as a result of both a federal government focus on accountability of higher education institutions and greater competition for the state funds traditionally directed to the colleges. Community colleges must collect and report graduation and transfer rates, based on the outcomes of fall semester cohorts of first-time, full-time students in degree programs, to meet the requirements of the Student Right-to-Know and Campus Security Act of 1990. This has resulted in some less-than encouraging statistics (The National Center for Higher Education Management Systems, 2009).

- Only 28% of first-time, full-time, associate degree-seeking CC students graduate with a certificate or an associate degree within three years.
- Fewer than half (45%) of students who enter CC with the goal of earning a degree or certificate have met their goal six years later.

- Slightly more than half (52%) of first-time, full-time college students in public CCs return for their second year.

The Center uses data from its three surveys—the Community College Survey of Student Engagement (CCSSE), the Survey of Entering Student Engagement (SENSE), and the Community College Faculty Survey of Student Engagement (CCFSSE)—to explore the challenges associated with college completion and how these strategies address them. While not all students enroll in CC for the purpose of attaining a degree, research has shown that the persistence patterns of those who intend to gain a degree or transfer are troubling and inconsistent (Driscoll, 2007).

A recent report by the Department of Education Statistics (2010) finds statistically significant differences in the graduation rates for students who begin at CCs as compared with those who start at a four-year institution. A six-year longitudinal study of over 19,000 students reported that of those who started at 2-year public institutions, 46% had not received a certificate, associate's degree or bachelor's degree. This compares with only 24% who started at four-year institutions who had not received a degree (Radford, Berkner, Wheelless, & Shepherd, 2010). To better determine the reason for this difference, data analysis is a critical part of understanding what variables influence student success as measured by the attainment of a bachelor's degree.

Social Integration and Success in Engineering

There have been numerous research studies showing increased retention rates for transfer students who develop connections to the university before and after transfer. Surveys generally find transfer students disengaged. In fact, one of the chief factors hurting retention is that transfer students are disconnected to the university at many key points (CCSSE, 2007).

As a result of this input, CCSSE institutions have responded to persistence issues in a variety of ways. Interventions include the development of learning communities, referral of students to learning support programs, development of course competency standards, requirement of orientation, and the implementation of early warning referral systems that institutions can use to improve student services and systems.

Programs that build strong social networks among students by grouping them together through their course sequence, place of residence, and other activities, have been shown to increase persistence. These networks foster student engagement and social interaction, leading to a greater sense of connection to their programs and universities (Springer, Stanne, & Donovan, 1999; Tinto, 1993). According to Nestor-Baker, and Kerkov (2009), cohort programs in particular have been shown to have a positive effect on the production of STEM graduates and they have a relatively low cost of implementation. This makes them an appealing option, particularly during times of resource constraints.

Numerous institutions have also taken it upon themselves to build partnerships that enable students to seamlessly transfer from a two-year to a four-year college. Because the process of preparing for transfer and the transition involved can be complex, students' chances of transferring and completing a baccalaureate degree are greatly enhanced when two-year and four-year institutions work together to facilitate the process and reduce barriers (CCSSE, 2007). Increasing the effectiveness of CCs will also increase pathways to engineering degrees. The book *Enhancing the Community College Pathway to Engineering Careers* (National Research Council, 2005) lists a lack of cooperation and coordination among high schools, CCs, four-year institutions, and state higher-education agencies as a factor keeping CC students from reaching their full potential.

The research of Handel (2007) and a 2005 National Academies (National Research Council, 2005) report recommend connection-based approaches in designing a successful CC student transfer process. These connections enhance CC students' engagement by building a bridge between CC pre-engineering students and university-level engineering programs. Research also shows that partnership-based strategies increase success for CC transfers (Pascarella & Terenzini, 2005; Tinto, 1997). To ensure success among students in CC and to better prepare them for transfer, research also points to the effectiveness of student support services, such as in-depth orientations, proactive advising, early warning systems, organized academic support for the transfer process, and financial aid policies (Jenkins et al., 2006).

Other university-based transfer center programs have also committed to increasing the number of students transferring to four-year institutions. The Transfer Experience and Advising Mentor (TEAM) Project at the University of Illinois helps CC students transfer to the university and succeed academically. It targets ten CC districts and provides information sessions, one-on-one advising, and peer mentoring to increase the amount of information being provided to CC students about transfer (Office of Community College Research and Leadership, 2007). The program also offers courses that have been shown to help students determine how to move toward specific majors. The University of California has focused its outreach efforts on CC counselors and transfer-center directors (Handel, 2007). All of California's CCs have developed transfer centers (Handel, 2007). This has allowed the University to work very closely with students and invest in professional development resources that help counselors meet the needs of students more effectively.

Policymakers and researchers have also identified improving articulation and transfer agreements at both the state and institutional level as key methods by which to improve

bachelor's degree attainment rates (Wellman, 2002). Despite all the research pointing to connections for successful transfer to the university, these agreements are difficult to create and difficult to sustain without adequate funding (Handel, 2007). Many of the programs end altogether when initial grant funding is over.

Successful partnerships are those where the partners communicate frequently, visit each other's campuses, meet frequently, and even share facilities (National Research Council, 2005). But, for several reasons, sustainable partnerships are difficult to build. The programs are often dependent on personal relationships among faculty or administrators between the institutions rather than on policies (National Research Council, 2005).

To promote sustainable partnerships, data about results are necessary. "As community colleges become more important in higher education in the United States, data will be necessary to evaluate both student and institutional outcomes and to answer the questions about the relationship between articulation agreements and recruitment, retention, and persistence to the B.S. degree of community college transfer students" (National Research Council, 2005, p. 67).

Academic Integration and Success in Engineering

Tinto (1993) defines academic integration as doing well in courses. Because of the significance of quantitative skills, academic integration may be as or more important than social integration upon entering college. Students with a C average or less have a high probability of leaving engineering (Veenstra, Dey, & Herrin, 2009; Zhang, Min, Ohland, & Anderson, 2006). Many studies measure academic integration using first-year grade-point average without specifically examining grades earned in core engineering course commonly

referred to in the literature as “gatekeeper” courses (Tyson, 2011). Even fewer studies include CC transfer grades as part of the data for success in “gatekeeper” courses.

Suresh (2006) found that a majority of engineering majors who earned a B minus or below in Calculus I, Calculus II, and Physics I—strategic “gatekeeper” courses—left engineering. The research in this dissertation builds on the work of Tyson (2011) and others by including CC grades: “a key element of academic and social integration that is unaccounted for in most studies of engineering retention” (Tyson, 2011, p. 763).

According to Suresh (2006) academic integration may be the most important factor for success for a transfer student at a college of engineering. “If one were to accept the idea that success/failure in barrier courses determines the ultimate success of a student in engineering, understanding student experiences in barrier courses will offer us a unique and useful lens through which to view the phenomenon of attrition” (Suresh, 2006, p. 217).

Background for Academic Integration

Levin and Wyckoff (1990) found predictors of retention were dependent on the students’ point of progress through the first two years of an engineering program. They used logistic regression to determine persistence at three time periods: pre-enrollment, the end of the freshman year, and the end of the sophomore year. The freshman year model identified grades in Physics I, Calculus I, and Chemistry I as the best predictors of retention. The sophomore year model identified the best predictors of retention as grades in Calculus II, Physics I, and Physics II. Most students who leave engineering do so before they have successfully completed these difficult courses (Levin & Wyckoff, 1990). The first-year of college is particularly important because 35% of science, technology, engineering and mathematics (STEM) majors switch after their first-year (Daempfle, 2003).

Data show that students must acquire proficiency in these key foundational areas to be able to succeed in engineering. In a longitudinal study of over 35,000 pre-engineering students at Purdue, 84% of those who left engineering did so before they completed their pre-professional program (Budny, LeBold, & Bjedov, 1998). LeBold and Ward (1998) also found that the freshman year is critical to retention and that the best predictors of retention were the first- and second-semester grades and the cumulative GPA. They found that student's perceptions of their problem-solving abilities in mathematics and science were also predictive of retention. Budny et al. (1998) looked specifically at the effect of first-year course performance on graduation and found a strong correlation between first-semester GPA and graduation rates in engineering.

Data regarding pathways to STEM careers indicate that a critical transition point exists in the first and second years of college. A high percentage of students leave their intended STEM majors during this time. Trends also indicate that the percentage of students leaving these majors is higher for female students and higher still for under-represented minority students (National Science Board, 2004, 2006; National Center for Education Statistics, 2009).

Whalen and Shelley (2010) agree that the single fundamental variable in predicting retention in science, technology, engineering, and mathematics (STEM) fields is grade point average. They found a dramatic increase in retention and/or graduation achieved by an average increase of as little as one-tenth of a percentage point increase in cumulative GPA. This suggests that doing what is necessary to improve grades must be the top priority for retaining engineering students. Earlier research by Strenta et al. (1994) found that low grades were the most common predictor for all students leaving science and engineering courses.

Schools have found that success strategies such as tutoring, supplemental instruction, and counseling are effective in helping students complete these high risk courses (Budny et al., 1998; Shelley & Hensen, 2003).

Retention research that applies to all students is also relevant to CC students. In their work on retention Whalen, Saunders, and Shelley (2010) found that variables such as first-year cumulative GPA, financial aid variables, learning community membership, information technology use in high school, and in-state residence were statistically significant predictors of retention from the first-year to the second year. Pre-college characteristics account for a small (though meaningful) percentage of the variation in retention rates (Zhang et al., 2004). However, research shows that pre-engineering success variables are weaker predictors of retention in engineering than are grades in core engineering courses (Budny et. al., 1998; Levin & Wyckoff, 1990). Further, the combination of grades in core engineering courses is a stronger predictor of success than any single course alone. In addition, science departments that have studied the cause of failure in these core courses agree that weak algebra skills are a common cause of failure. Tsapogas (2004) notes that GPAs tend to be lower for transfer students: “Science and engineering graduates with lower undergraduate grade point averages (GPAs) were more likely to have attended CC than were graduates with higher grade point averages. Fifty percent of S&E [science and engineering] graduates with less than a 2.24 GPA (mostly C’s) reported that they had attended CC before receiving their S&E degrees, compared with 42 percent of those with an undergraduate GPA of 3.75–4.00 (mostly A’s)” (Tsapogas, 2004, p. 33).

It is important to note that not all students leave engineering because of bad grades (Ohland et al., 2004). Conversely, not all students who stay in engineering have good grades.

Despite finding specific effects of academic achievement in prerequisite courses, Suresh (2006) also found that highly motivated students persist despite low achievement.

Mathematics Preparation

Academic integration in engineering includes sufficient preparation in mathematics and science. A central problem is that U.S. students consistently score below the international average in mathematics and science (Brainard, 2008). In addition the ACT College Readiness reports that 78% of high school graduates did not meet the readiness benchmark levels for one or more entry-level college courses in mathematics, science, reading, and English. The ACT estimates that students meeting the readiness standard in a given subject have a 75% chance of getting a C and a 50% chance of getting a B in an entry-level course (ACT, 2008).

Placement in pre-calculus has validity in increasing success rates. Purdue University found that students placed in pre-calculus who successfully mastered the material (defined by an A in the course) were enabled to have similar retention rates as those with mathematics SAT score advantages of up to one hundred points (Budny et al., 1998).

Collaborative Learning Strategies for Success in Difficult Courses

Collaborative learning strategies are a well-documented way to increase grades in difficult courses (Martin & Arendale, 1993). “Many men and women who form study groups report that they both enjoy their work more and feel they learn more because of the academic discussions in these groups” (Light, 1990, p. 18). “Collaborative learning strategies solve two of the most vexing pedagogical programs; large class sizes and gross differences in education preparation” (Light, 1990, p. 17).

Supplemental Instruction (SI) has been shown to increase academic achievement in difficult-to-pass courses like calculus and physics. The Center for Supplemental Instruction

at the University of Missouri-Kansas City found that: “Students participating in SI within the targeted historically difficult courses earn higher mean final course grades than students who do not participate in SI. SI participants withdraw from classes at a lower rate and receive a lower percentage of D or F final grades than those who do not participate in SI, and students participating in SI persist at the institution at higher rates than non-SI participants” (Center for Supplemental Instruction, 1998, pp. 2-3). Shelley and Hensen (2003) validated these claims. After controlling for student’s pre-entry characteristics, they found that SI participants in engineering mathematics and physics courses earned significantly higher percentages of A and B grades, significantly lower percentages of D and F grades and withdrawals, and significantly higher mean final course grades than did non-SI participants.

Addressing Student Perceptions of Engineering

Students leave engineering for a variety of reasons. Social and academic integration into the university, of which preparation in mathematics and science are important factors, provide compelling reasons why a student might stay or leave. Another factor affecting retention is the student’s perception of the engineering profession. Suresh (2006) explains “students come into engineering with very limited knowledge about the requirements of the program and understanding of the engineering profession. They do not understand the connection between the theoretical courses they are required to take and the application to their profession” (Suresh, 2006, p. 236). This lack of knowledge is a factor in students’ decision to transfer out of engineering. Therefore, it is important for students to have early understanding of the engineering profession which will give them a vision past the theoretical coursework.

Summary

The challenge to provide enough STEM graduates has been summarized by the Business Higher Education Forum (2011):

- 1) Failure to attract undergraduate students to STEM studies. “Fewer than one in three college-bound high school seniors is interested in STEM and about one in six is both interested in STEM and proficient in mathematics, the critical gatekeeper to STEM courses, majors, and careers” (Meeting the STEM Workforce Challenge, 2011, p. 1). Low levels of interest in STEM and proficiency in mathematics reflect a long-term challenge that appears stubbornly resistant to improvement (BHEF, Leveraging, 2011).
- 2) Failure to retain students who enroll in STEM education. More than half of all students enrolling in STEM disciplines move to non-STEM majors before graduation, 35% in the first-year of study (Daempfle, 2003). The exodus among women and underrepresented minorities is especially high (National Center for Education Statistics, 2009).
- 3) Even after graduating with STEM degrees, nearly half of all STEM degree holders choose to enter non-STEM fields. In engineering, more than half of engineers enter non-STEM jobs (Meeting the STEM Workforce Challenge, 2011).

This work will add to the body of research that Tyson (2011) found lacking. Specifically, the research addresses engineering and CCs and examines the impact of taking prerequisite courses at CCs as opposed to the University. It is estimated that CCs now educate about 44% of all undergraduates in the United States (American Association of Community Colleges, 2011). Although more high school graduates are choosing to attend

CCs to fulfill curriculum requirements, other first-year retention research in engineering omits CC attendance in their models of freshman engineering retention. In addition, this dissertation will focus on practical applications of these results to inform policy on intervention strategies at both types of institutions and create achievement recommendations in core engineering courses. Selected recommendations may be applicable to non-transfer students as well.

This dissertation is written in a three-paper format in which all of the papers are based on the National Science Foundation Talent Expansion Program initiative. Recognizing the importance of increasing the number of graduates in STEM fields, the National Science Foundation (NSF) has funded the Science Technology Engineering and Mathematics (STEM) Talent Expansion Program (STEP). One initiative of the STEP program is the Student Enrollment and Engagement through Connections (SEEC) project. SEEC is a collaborative, connection-based alliance between a large Midwestern state university (SU) and an in-state CC to increase success of CC transfers to engineering. This research also takes advantage of the articulation agreement between all in-state CCs and SU to track retention and graduation rates of students based on variables at both institutions.

Dissertation Papers

Dissertation Questions

The aim of this dissertation is to examine and collect data to better understand the reason for failure to retain CC transfer students in engineering by addressing the following research questions:

1. What social integration strategies improve retention for CC transfer students in the College of Engineering at SU?

2. What academic integration variables improve retention for CC transfer students in the College of Engineering at SU? How do these compare with students who enter the College of Engineering directly from high school?
3. What statistical models predict retention and/or graduation in engineering for CC transfer students in the College of Engineering at SU?
4. How can these results be applied to inform students, advisors, and institutions so as to increase the number and diversity of graduates in the College of Engineering?

Dissertation Papers

The first three research questions will be addressed by individual papers that have been submitted for publishing consideration. The fourth question will be addressed within each paper and in the dissertation conclusions. The titles and objectives of each paper are:

1. Connection strategies influential to success in engineering for CC transfer students.

The paper has been submitted to the *Journal of Engineering Education*, Special STEM Issue. The objective of this study is to determine whether or not the Engineering Admissions Partnership Program (E-APP) and its interventions result in a set of improved outcomes for transfer students. The E-APP offers CC transfer students' connections to the university through coordinated academic advising, peer-mentoring, campus visits, and online social and professional networks. The hypothesis is that students participating in the E-APP will have greater success in pursuing an engineering degree than students who do not participate in the E-APP. Persistence will be measured by enrollment, transfer rates, and retention rates of the E-APP participants. The results of this research will inform research and best-practices, resulting in increased success of transfer students into engineering.

This study contributes to the data-based body of evidence about successful cooperation-based strategies for CC students in the STEM field of engineering.

2. The role of academic integration on success in engineering for CC transfer students.

This paper has been submitted to the *Journal of Community College Research and Practice*. This study provides much-needed research about academic integration into engineering by the impact of taking prerequisite core engineering courses at a CC as opposed to the university. In this study the core-engineering courses that are common to all engineering majors at SU are called the Basic Program (BP) in engineering. All students must successfully complete this BP with a minimum of a C average (2.0 on a 4.0 scale) to graduate in engineering.

This study uses student achievement in the overall BP grade-point average and grades in Calculus I, Calculus II, and Physics I as measures of academic integration that may influence engineering degree attainment. It examines the impact of taking these core courses at the CC as opposed to the university. Understanding the variables that impact a student's ability to deal with BP courses will allow for more targeted recruitment and focused intervention strategies to help students who are struggling with difficult courses.

3. Predicting graduation rates in engineering for CC transfer students.

This paper will be submitted to the *Journal of Applied Research in the Community College*. This paper reports on the research strategy of using boosted logistic models to predict success in engineering. The boosted regression logic is a relatively new strategy for retention and graduation rate research (Schonlau, 2005; Hastie, Tibshirani, & Friedman 2001). In this study it is used to determine which academic variables exert the greatest

influence on predicting graduation in engineering. Specific models are developed based on academic and demographic variables for CC transfer students.

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CHAPTER 2. CONNECTION STRATEGIES INFLUENTIAL TO SUCCESS IN ENGINEERING FOR COMMUNITY COLLEGE TRANSFER STUDENTS

A paper submitted to the *Journal of Engineering Education*, Special STEM Issue

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Abstract

This study contributes to the body of evidence on successful cohort-based strategies for community college transfers into the field of engineering. The study design provides a unique opportunity to measure longitudinal data for community college students who are participating in the Engineering Admissions Partnership Program (E-APP), and their success after they transfer into the College of Engineering at a large Midwestern land-grant university. Descriptive and inferential statistics are employed to investigate how student background characteristics, participation in the E-APP and learning communities influence various student outcomes.

Introduction

The global marketplace is characterized by dependence on knowledge in science and technology, yet the percentage of Americans who receive degrees in science, technology, engineering and mathematics (STEM) is estimated to be less than 16% of total bachelor's degrees awarded. This is substantially less than that of China (47%), South Korea (38%) and Germany (28%) (National Science Board, 2010). At the same time, the demand for STEM workers is growing faster than the supply (Increasing the Number of STEM Graduates, 2010). More than half of all students who enroll in STEM disciplines change to non-STEM majors before graduation. The exodus to non-STEM majors among women and

underrepresented minorities is particularly acute (National Center for Education Statistics, 2009).

As America seeks to graduate more engineers and scientists, community colleges provide a vital source of students for four-year colleges and universities. It is estimated that community colleges now educate about 44% of all undergraduates in the United States (American Association of Community Colleges (AACC, 2011). Community-college leaders believe that providing a more level institutional playing field is consistent with the federal government's traditional role in ensuring equality of opportunity in higher education (Baime, 2011).

Community colleges bring education closer to Americans through affordability, proximity and diversity (AACC, 2011). Furthermore, community colleges are a cost-effective means of working toward a bachelor's degree. According to data compiled by the College Board and the American Association of Community Colleges (AACC) in 2009, tuition and fees at community colleges average only 36.2% of the average four-year public college tuition and fee bill. Community colleges are also within driving distance of most Americans (AACC, 2009). Of the eight million community college students currently enrolled in for-credit courses, 42% are the first in their family to attend college, 46% are receiving financial aid, and 45% are from an underrepresented ethnic minority group (AACC, 2011). Moreover, students from underserved groups, especially Hispanic and Native Americans, have traditionally enrolled in community colleges in greater numbers than in public four-year institutions. These relative proportions are likely to increase as the population of students from underrepresented ethnic groups is expected to increase substantially in the coming decades (AACC, 2011).

In addition, students from community colleges may be more likely to stay in-state once they have finished their education, especially in high-demand fields such as engineering. In a recent study at Iowa State University, Laugerman and Mickelson, (2011), found a significantly higher percentage of engineering graduates who were transfers from community colleges took jobs in state as compared to non-transfer students.

However, the educational effectiveness of community colleges is under new scrutiny as a result of both a federal government focus on accountability of higher education institutions and greater competition for the state funds traditionally directed to the colleges (The National Center for Higher Education Management Systems, 2009). Community colleges are required to collect and report graduation and transfer rates. The outcomes of fall semester cohorts of first-time, full-time students in degree programs must be recorded to meet the requirements of the Student Right-to-Know and Campus Security Act of 1990. An analysis of these data have resulted in some surprising findings (The National Center for Higher Education Management Systems, 2009).

- Only 28% of first-time, full-time, associate degree-seeking community college students graduate with a certificate or an associate degree within three years.
- Fewer than half (45%) of students who enter a community college with the goal of earning a degree or certificate have met their goal six years later.
- Slightly more than half (52%) of first-time, full-time college students in public community colleges return for their second year.

The National Center for Higher Education Management Systems obtains data from its three surveys — the Community College Survey of Student Engagement (CCSSE), the Survey of Entering Student Engagement (SENSE), and the Community College Faculty

Survey of Student Engagement (CCFSSE) — to explore the challenges associated with college completion as well as strategies that will address these challenges.

As community colleges increasingly rely on data to inform institutional decisions about best practices, longitudinal data are needed to assess students' progress through educational institutions. However, an assessment of student level data is dependent on data structures, policies, and practices, which are difficult to coordinate between community colleges and universities (Mullin, 2011). This study provides a unique opportunity to measure longitudinal data for community college students as they progress through the university before and after transfer into an engineering program. A major outcome of the data analysis between the community college and the university will be the development of effective strategies to increase the success of community college transfer students in engineering.

Background

One of the chief factors hurting retention is that transfer students are disconnected to the university at many key points (CCSSE, 2007). Surveys of transfer students find many disengaged, thus decreasing retention rates. Responding to the need for increased persistence of community college students at four-year institutions prompts the need for increased connections to the university by the students. Numerous institutions have taken it upon themselves to build partnerships that enable students to transfer seamlessly from a two-year to a four-year college (CCSSE, 2007). Because the process of preparing for transfer and the transition involved is complex, students' chances of transferring and completing a baccalaureate degree are greatly enhanced when two-year and four-year institutions work together to facilitate the process and reduce barriers (CCSSE, 2007).

Policymakers and researchers have identified improving articulation and transfer agreements at both the state and institutional level as a key method by which to improve bachelor's degree attainment rates (Wellman, 2002). Creating such agreements is no easy task, as it requires faculty and institutions to agree on which courses properly prepare students and requires them to review and potentially revise their courses (Handel, 2007).

Additionally, *Enhancing the Community College Pathway to Engineering Careers* (National Research Council, 2005) lists a lack of cooperation and coordination among high schools, community colleges, four-year institutions, and state higher-education agencies as a factor keeping community college students from reaching their full potential. Cohort programs in particular have been shown to have a positive effect on the retention of STEM graduates (Nestor-Baker & Kerkor, 2009), and they have a relatively low cost of implementation, which makes them an appealing option, particularly during times of resource constraints.

Recognizing the importance of increasing the number of graduates in STEM fields, the National Science Foundation (NSF) has funded the Science Technology Engineering and Mathematics (STEM) Talent Expansion Program (STEP). One initiative of the STEP program is the Student Enrollment and Engagement through Connections (SEEC) project. SEEC is a collaborative, connection-based alliance between a large Midwestern land-grant state university (SU) and a community college (CC) to increase success of community college transfers to engineering.

To this end, the Engineering Admissions Partnership Program (E-APP) was created in 2008 as a SEEC project initiative. The creation of the E-APP was inspired by the research of Handel (2007) and a 2007 National Academies (National Academy of Engineering, 2007)

report which recommended connection-based approaches in designing a successful community college student transfer process. These connections enhance community college students' engagement by building a bridge between community college pre-engineering students and university-level engineering programs. Research has shown that partnership strategies increase success for community college transfers (Pascarella & Terenzini, 2005; Tinto, 1997).

Conceptual Framework

Conceptual framework models provide a visual illustration of implicit and explicit assumptions concerning the actions required to solve a problem and why the problem will respond to the actions (Chen, 2005). They also illustrate how the contextual factors and program activities are organized for implementing the intervention and supporting the change process (action model). The SEEC project conceptual framework in Figure 1 (Laanan, Rover, Bruning, Mickelson, Shelley, Laugerman, Darrow, & Pontius, 2011) illustrates the progression of a CC student toward a degree in engineering and the relevant SEEC intervention strategies. This model reflects the many variables which may impact the engineering transfer student. Furthermore, the contributing components of success in engineering are also illustrated in the model. The SEEC project hopes to improve and refine these components through connections. Finally, the model illustrates the role of the E-APP in transfer student success.

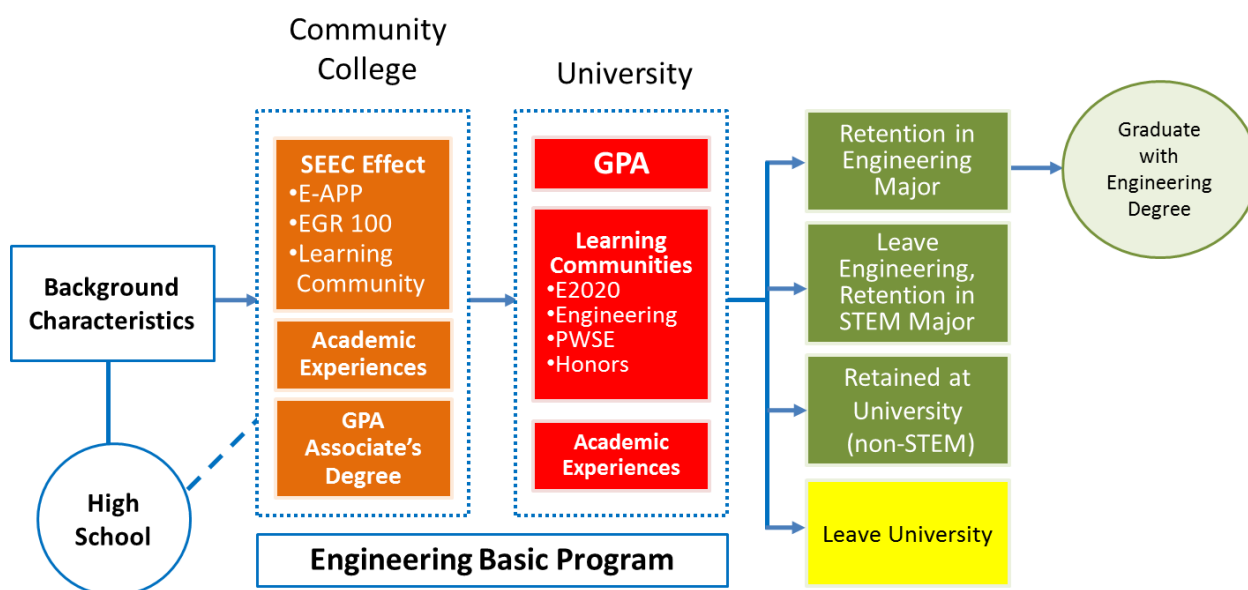


Figure 1. SEEC model conceptual framework

Objectives

This project aims to contribute to the data-based body of evidence characterizing successful cohort-based strategies for community college transfers to the STEM field of engineering. It provides a unique opportunity to measure longitudinal data for community college students participating in the E-APP and their success after they transfer to the College of Engineering. The focus is on the SEEC effect in the conceptual model (Figure 1) which includes the E-APP, Engineering 100 (engineering orientation offered at the CC), and learning communities offered to students before and after transfer.

Several programs have been created to address connection-based needs of transfer students. These include university learning communities such as The Engineer of 2020 (E2020) Scholars Program in the College of Engineering for first-year and transfer students who demonstrate academic potential and financial need. Program participants must also be interested in learning about leadership, entrepreneurship, global thinking, and systems

thinking within engineering. Other learning communities include engineering departmental learning communities, the Program for Women in Science and Engineering (PWSE), and the Honors learning communities. In addition, the E-APP offers CC transfer students a connection strategy of coordinated academic advising and peer-mentoring (Laanan, Rover, Mickelson, Shelley, & Bruning, 2009).

The objective of the study is to determine whether or not the E-APP and its interventions result in a set of improved outcomes for transfer students. It is hypothesized that students participating in the E-APP will have greater success in pursuing an engineering degree than students who do not participate in the E-APP. Persistence is measured by enrollment, transfer rates, and retention rates of the E-APP participants. The results of this paper will inform research and best-practices that may result in increased success of transfer students to engineering.

Research Design and Methodology

A mixed-method evaluation strategy including both quantitative and qualitative evaluation methods is utilized. This includes data from the SU's Office of Admissions, College of Engineering, and Office of Institutional Research with longitudinal student records.

The evaluation of the E-APP includes performance monitoring and assessment, formative evaluation and program review, and summative evaluation as appropriate for the implementation and outcome project stages. A conceptual logic model of the E-APP is constructed in Tables 1a and 1b to monitor the program's performance and evaluate its outcomes. The logic model illustrates the rationale behind the program, the chain of events within the program, and the desired outcomes or goals. Logic models identify program

elements and show expected connections among them, providing a link to evaluation approaches that stress the importance of having a theory of change that underlies a project (Frechtling, 2007).

Design Features: Ex-post Evaluation and Quasi-experimental Applications

For the evaluation of the E-APP a true experimental design cannot be constructed, as the participants are limited to pre-engineering CC students who signed up for the E-APP. In this case, a quasi-experimental design, in which a matched (but not randomly assigned) comparison group is included, was more feasible. Thus, quasi-experimental data are used to compare different groups of engineering students at the SU, those who participated in the E-APP and those who did not.

This study uses an ex-post evaluation approach for estimating treatment impacts of the E-APP. Using before-after comparisons to evaluate the effectiveness of the E-APP; key indicators are enrollment rates, transfer rates, and retention rates. This also includes evaluations of other connection-based strategies that are integrated with the E-APP.

Multi-stage Method

To determine program effectiveness of the E-APP in increasing the success and diversity of CC transfers to SU's College of Engineering, a multi-stage evaluation was utilized. The E-APP is in both its implementation stage (beginning its fifth year), and the initial outcome stage (this is the final year of the NSF SEEC project). The evaluation includes a program review and student performance monitoring and assessment, with formative and summative evaluation as appropriate for the implementation and outcome project stages. To guide evaluation, a conceptual logic model of the E-APP was constructed to monitor the program's performance and evaluate its outcomes.

Data Collection

In relation to transfer student success, various background characteristics, academic data, and student experiences were analyzed for participants and non-participants in the E-APP and its integrated strategies of Engineering 100 and learning communities. Data include semester-by-semester transcript information for approximately 13,400 students who were admitted to the College of Engineering from Fall of 1999 through Fall of 2011. To understand the success variables for in-state community college transfers to engineering, the SEEC project collected data from Fall 2002 to Fall 2008. The data set includes academic and demographic variables for 1,191 in-state community college transfer students to the College of Engineering. These datasets are large enough for the observations to be reliable and give sufficient power to the statistical tests (Levine, 2008).

Validity and Reliability

The mixed-methods approach increases both the validity and reliability of the study (Chen, 2005). Reliability is the "consistency" or "repeatability" of the measures. Because the samples are drawn from complete university data sets, the sample size is large enough for the observations to be reliable. The measure of participating in the E-APP or not participating in the E-APP has a high validity. For this reason, the results of this study are transferrable to other community colleges and colleges of engineering. The learning communities and networking interventions, components of the E-APP, could be applicable to other community colleges and universities in the state and around the nation.

The data were analyzed statistically for significant differences between the quasi-experimental groups (E-APP or no E-APP). For categorical or binary variables, the Pearson chi-square statistic with one degree of freedom was used. In each test the assumption that

expected frequencies are all greater than or equal to 5, which allows for the normal approximation to a binomial variable, was met (Levine, 2008). Validity of the chi-square test also is predicated on the assumption of random sampling without replacement from a large normally distributed population. For numerical variables, the *t*-test for the equality of two means assuming equality of variance was used. The assumption of equality of variance between the groups was tested using a *F*-test based on the ratio of larger variance to variance before the *t*-test was used as appropriate for either the equal-variances or unequal-variances situation. The level of significance used was 0.05, unless otherwise noted.

Descriptive and inferential statistics are employed to investigate how student background characteristics, academic variables, and participation in the E-APP, Engineering 100, and learning communities influence various student outcomes.

Direct Indicators of E-APP Success

The SEEC project is a direct connection between the SU and the CC. However, the E-APP is offered to all in-state community college transfers. In addition to comparing the E-APP with the non-E-APP groups, comparisons are also made for recent retention data with the historical averages to see if significant improvement in student outcomes has been achieved.

To establish a baseline for comparison of retention rates, average first-year retention rates were determined for both the CC and all in-state community colleges. These are based on a seven-year period of historical data collected from 2000 to 2007, before the SEEC project was implemented. Where sample groups are not large enough from the CC for comparison, data for all in-state community college transfers were substituted since all of the

benefits of the E-APP were available to all in-state community college transfer students.

Direct indicators of success for the E-APP include:

- 1) communication of the E-APP message between the CC and the SU
- 2) increasing enrollment numbers and participation rates in the E-APP
- 3) increasing matriculation numbers of the E-APP students as represented by the SU's Admissions Partnership Program (APP) matriculation numbers that include the E-APP
- 4) increased first-year retention of the E-APP transfer students over the non-E-APP transfer students
- 5) E-APP retention comparisons matched on average mathematics ACT score (to overcome any self-selection bias in the quasi-experimental groups)
- 6) increased first-year retention of the APP students over the non-APP students (which include the E-APP students) for validation
- 7) increased first-year retention rates of CC admits to the College of Engineering over pre-SEEC retention rates
- 8) increased first-year retention rates of in-state community college transfers to the College of Engineering over pre-SEEC retention rates

Integrated Indicators of the E-APP Success

The integrated indicators of the E-APP success include:

- 1) increasing total enrollment and increased numbers of women and minorities in pre-engineering at all in-state community colleges
- 2) increasing enrollment in Engineering 100 (engineering orientation) at the CC

- 3) increasing percentages of in-state community college transfers to engineering participating in a learning community at the SU

Results

E-APP Program Logic Model

The E-APP logic model (Tables 1a and 1b) illustrates the resources, activities, and outputs of the program along with the short- and long-term outcomes and assessment measures of the project. The short-term and long-term outcomes have been combined due to the short implementation time of the project. There are no long-term outcomes yet.

Each of the program activities (Table 1a) represents a connection between the transfer student and the university. The activities of the logic model provide channels of engagement for the community college student in the College of Engineering. According to focus group data, the most meaningful touch points were interactions with the academic advisor and peer mentor (Laanan, Rover, Mickelson, Shelley, & Bruning, 2009). The assessment progress outcomes are the measures of success for the E-APP.

Table 1a The E-APP Logic Model

RESOURCES	ACTIVITIES	OUTPUTS
In order to accomplish our set of activities we will need the following (or we have the following on hand).	In order to address our goal(s) we will accomplish the following activities.	What are the tangible products of our activities? (what do we expect to see as a result of our activities)
Seeking Enrollment and Engagement through Connections (SEEC) Team Members	Since the E-APP Learning Community is primarily virtual, much of the “activity” occurs through electronic means.	Engineering has customized the University APP program with E-APP to support in-state community college transfer students to engineering
SEEC Grant Funding Transfer Advisors Graduate Assistants Undergraduate Peer-Mentors College of Engineering Faculty and Staff Admissions Programs	Professional Network Academic Advising Peer-Mentoring Transfer Student Campus Visits Engineering Career Fairs Transfer Student Events Social Network	Transfer programming recommendations Posters and brochures Network between CC and SU Data sharing between CC and SU Advisor training for CC and SU academic advisors Peer mentor training

Table 1b The E-APP Logic Model (continued)

SHORT TERM OUTCOMES	LONG TERM OUTCOMES	ASSESSMENT: Measuring Progress
What changes do we expect to occur within the short term? (one year)	What changes do we want to see occur after that?	What will we measure to determine progress towards team objective & grant goals?
Transfer students are entering engineering with a clear plan and connections that will make for smooth transition and increased retention		Quantitative and qualitative measures of success for transfer students to the College of Engineering
Dissemination of student success reports and best practices Key learning experiences and professional development of transfer students Proactive transfer process for engineering students with multiple points of engagement Increased number of engineers Increased diversity of engineers Increased in-state retention of engineering graduates Web-based support network Connections between students, faculty , staff and facilities at CC and SU Creation of engineering departmental transfer learning communities at SU Creation and support of CC Pre-Engineering Learning Community State Public Policy supporting transfer-friendly culture		Success in core engineering courses Increased enrollment in pre-engineering at CC Increased enrollment in Engineering 100 at CC Increased enrollment in engineering LC at CC Increased participation in E-APP Increased matriculation rates from CC and SU Increased participation by transfers in learning communities at SU Increased retention rates in Engineering Increased retention rates at SU Increased graduation rates in Engineering Increased graduation rates at SU

The outputs include peer mentors—successful community college transfers to engineering who are selected to mentor pre-engineering community college students. The peer mentors make frequent contact with the E-APP students through both social and professional online networks. The goal is to connect students at the CC with the SU in as

many ways as possible. This includes on-campus activities that allow them to feel part of the university community and to prepare them for transfer into the engineering academic community. Engineering 100, which is offered at the CC, is another connection providing information about the engineering profession, transfer course equivalencies, degree program transfer plans, and individual degree programs within engineering as indicated on the conceptual model shown in Figure 1.

Direct Indicators of E-APP success

To determine the effectiveness of the E-APP, specific indicators of success based on the logic model outcomes of the E-APP were measured. This includes direct indicators of success of the E-APP as well as the success of other cohort strategies that are integrated with the E-APP.

The direct indications of success of the E-APP include the following:

Communication of the E-APP message between the CC and SU

Advisors and administrators at community colleges have adopted and promoted the E-APP and other connection-based programs as communication of results increases. Successful messages to the CCs stakeholders resulted in the creation of a new pre-engineering brochure with the following recommendations:

- Join the E-APP—those in the E-APP are retained at significantly higher levels
- Visit frequently with the SU academic advisor
- Meet with your peer mentor
- Get to know other students at both institutions
- Join a learning community, to enhance the opportunity for a higher probability of retention

- Obtain grades of B in all core engineering courses (Laugerman, Rover, Bruning, Laanan, Mickelson, & Shelley, 2011)
- Stay connected after transferring from the CC to the SU

Student feedback from the E-APP participants has been positive. Examples include:

- “The on-line group was a good way to keep up with University events that were relevant to me.” male, sophomore.
- “E-APP helped me get ready for the University by getting a University adviser, student ID card, and knowing that all my classes were going to transfer.” male, junior.
- “E-APP was a really good experience. I was especially pleased that the program guided me to take only classes that would transfer to the University. I also took advantage of cross enrollment courses that allowed me to get my feet on the University campus and interact with professors and students.” male, junior.

Increasing enrollment numbers and participation rates in the E-APP

Enrollment in the E-APP has steadily increased over the last 5 years, as shown in Table 2.

Table 2. Total enrollment in the E-APP from all in-state community college transfers

E-APP Enrollment	2007	2008	2009	2010	2011
Total	59	79	136	137	145

Tables 3 and 4 indicate higher participation rates in the E-APP at the CC (32.9%), where the E-APP is strongly promoted over those of all in-state community college transfers (17.9%). These tables also show much room for improvement in participation rates.

Table 3. Percent participation in the E-APP for CC transfer students to the SU College of Engineering

SEEC Project CC Percent Participating in the E-APP	
E-APP	32.9%
Non-E-APP	67.1%

Note: for years 2008, 2009, and 2010

Table 4. Percent participation in the E-APP for all in-state community college transfer students to engineering

All In-State CC Transfers Percent Participating in the E-APP	
E-APP	17.9%
Non-E-APP	82.1%

Note: for years 2008, 2009, and 2010

Increasing matriculation numbers of the E-APP students

Matriculation is represented by SU Admissions Partnership Program (APP) matriculation numbers, which include the E-APP.

The number and percentage of students in the E-APP who successfully matriculate to the SU will not be available until the E-APP has been in place for a longer time. However, as an early indicator of successful matriculation, university APP data can be substituted, which includes the E-APP data. Since the program started in Fall 2006, a total of 1,700 students have participated in the APP from all in-state community colleges. As of Sept 30, 2011, there are 502 active participants. A total of 695 have matriculated (transferred).

Increased first-year retention of E-APP transfer students over non-E-APP transfer students

Table 5 shows that for all in-state community college transfers to engineering, retention of the E-APP students is greater than for the non-E-APP students in both

engineering and at the SU overall. There is a statistically significant improvement in the percentage retained at the SU for the E-APP participants.

Table 5. Treatment effect for all in-state community college admits to engineering at the SU

E-APP Effect	All In-State Community College Admits to Engineering Admit Years 2008, 2009, 2010 Combined				
Treatment	Retained in Engineering, n	% Retained in Engineering	Retained at State University, n	% Retained at State University	Total, n
E-APP	62	73.8%	77	91.7%	84
Non E-APP	258	66.8%	313	81.1%	386

Notes: Significant differences at 0.05 are in bold, retention rates are for first-year

Table 6 shows the CC retention rates in engineering and the retention rates for CC students at the SU are both significantly higher for the E-APP participants.

Table 6. Treatment effect for CC students admitted to engineering at the SU

E-APP Effect	CC Admits to Engineering Admit Years 2008, 2009, 2010 Combined				
Treatment	Retained in Engineering, n	% Retained in Engineering	Retained at State University, n	% Retained at State University	Total, n
E-APP	40	76.9%	47	90.4%	52
Non E-APP	62	58.5%	81	76.4%	106

Notes: Significant differences at 0.05 in bold, retention rates are for first-year

E-APP retention comparisons based on average mathematics ACT score

Table 7 compares the average mathematics ACT for the E-APP group and the non-E-APP group of students. This is done to control for any self-selection bias in the quasi-experimental groups. . The results show there is no statistically significant difference between the mathematics ACT scores for each group. This is another indicator that the E-APP students have a statistically higher retention percentage than do the non-E-APP students when based on average mathematics ACT scores.

Table 7. Treatment effect for all in-state community college students admitted to the College of Engineering at the SU

E-APP Effect	All In-State Community College Admits to Engineering Admit Years 2008, 2009, 2010 Combined				
Treatment	% Retained in Engineering	% Retained at State University	Average Math ACT score	ACT n	Total N
E-APP	74%	92%	24.6	57	84
No E-APP	67%	81%	25.1	217	386

Notes: Significant differences at 0.05 in bold, retention rates are for first-year

Table 8. Treatment effect for CC students admitted to the College of Engineering at the SU

E-APP Effect	CC Admits to Engineering Admit Years 2008, 2009, 2010 Combined				
Treatment	% Retained in Engineering	% Retained at State University	Average Math ACT score	ACT n	Total N
E-APP	77%	90%	24.2	33	52
No E-APP	58%	76%	24.6	47	106

Notes: Significant differences at 0.05 in bold, retention rates are for first-year

Increased first-year retention of APP students over non-APP students

To validate these data, university-wide APP data were obtained. The University-wide APP dataset includes the E-APP data. The APP program is open to all in-state community college transfer students in any major. Table 9 shows that first-year retention rates of participants in the APP were significantly higher than for the non-APP students for the Fall 2007-2010 cohorts at the 0.05 level of significance.

Table 9. First-year retention rates of the APP transfers as compared to the non-APP transfers

Treatment	Fall 2007	Fall 2008	Fall 2009	Fall 2010
APP	88%	85%	92%	93%
No-APP	77%	70%	79%	76%

Notes: Significant differences at 0.05 in bold, retention rates are for first-year

Increased first-year retention rates of the CC students admitted to the SU College of Engineering over pre-SEEC retention rates

Table 10 shows significant gains in retention at the SU for the CC transfers to engineering since the implementation of SEEC and the E-APP. There were no statistically significant differences in background characteristics between the pre-SEEC and SEEC groups.

Table 10. First-year retention rates of CC students admitted to the SU College of Engineering

Admit Years	% Retained in Engineering	% Retained at State University	% Leave University	Sample Size
Pre-SEEC (2000-2007)	58.1%	72.6%	27.4%	275
SEEC (2008-2010)	64.7%	82.4%	17.6%	136

Notes: Significant differences at 0.05 in bold, retention rates are for first-year

Increased first-year retention rates of in-state community college transfers to the SU College of Engineering over pre-SEEC retention rates

Table 11 shows significant gains in retention at the SU for all in-state community college transfers to engineering since the implementation of SEEC and the E-APP. There were no statistically significant differences in background characteristics between the pre-SEEC and SEEC groups.

Table 11. First-year retention rates of all in-state community college students admitted to the SU College of Engineering

Admit Years	% Retained in Engineering	% Retained at State University	% Leave University	Sample Size
Pre-SEEC (2000-2007)	65.0%	79.9%	20.1%	841
SEEC (2008-2010)	68.6%	84.3%	15.7%	407

Notes: Significant differences at 0.06 in bold, retention rates are for first-year

Integrated Indicators of E-APP Success

Table 12 shows increasing participation in pre-engineering at all in-state community colleges as well as increasing participation of women and minorities in pre-engineering.

Table 12. Pre-engineering enrollment at all in-state community colleges

Pre-Engineering Students	2008-2009	2009-2010	2010-2011
Total	42	153	198
Women	8	15	25
Minorities	10	18	33

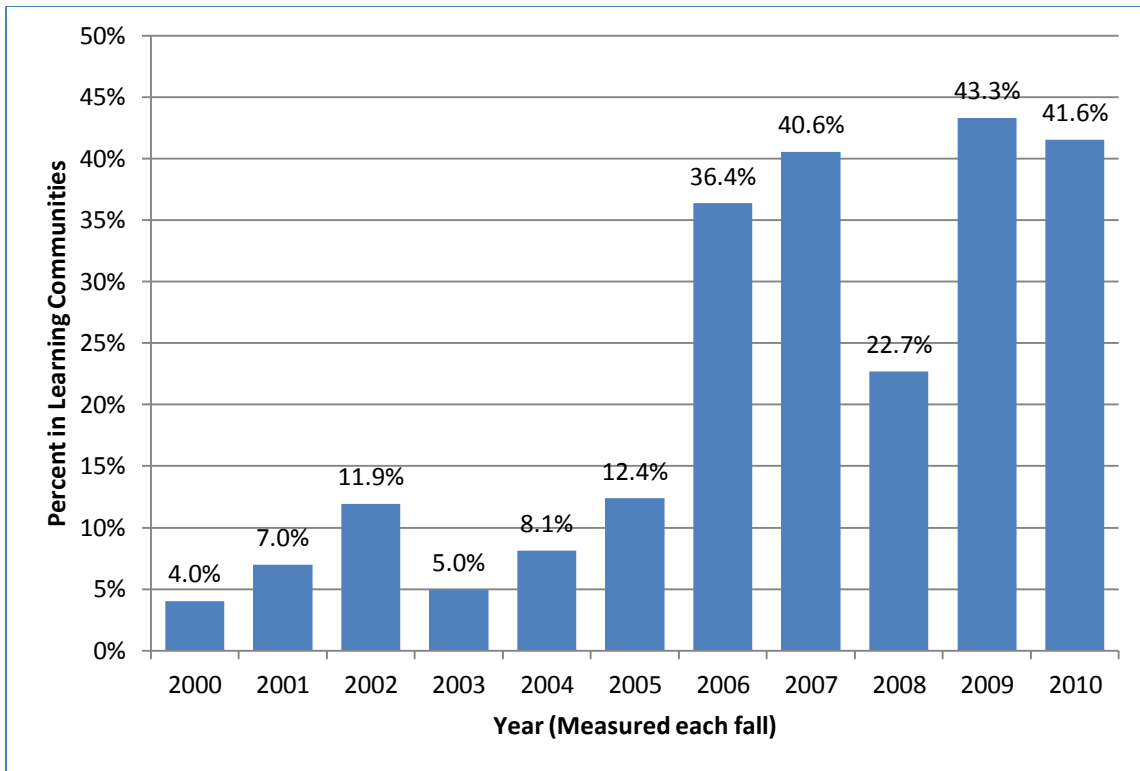
Note: numbers do not include summer enrollment

Enrollment is also increasing at the CC in Engineering 100 (Table 13), the engineering orientation course that was a SEEC initiative. This was an integrated strategy with the E-APP and an indirect measure of the E-APP's success.

Table 13. Enrollment in engineering 100 at the CC

Engineering 100 Students	2007-2008	2008-2009	2009-2010	2010-2011
Total	13	34	39	59

The percentage of in-state community college transfers who are participating in learning communities (other than the E-APP, which is measured separately) at the SU is generally increasing (Figure 2). The SEEC project helped to increase the number of engineering learning communities among College of Engineering departments and helped to establish learning communities specifically for transfer students at the SU. Since learning communities were an integrated strategy with the E-APP, this was also an indirect measure of success of the E-APP.



*Excluding E-APP

Figure 2. Percentage of in-state community college transfers who participate in a learning community at the SU

Conclusions and Recommendations

In these times of increased emphasis on accountability and measurable student outcomes, the SEEC project, informed by research and practice, has implemented strategies to increase the success of community college transfer students into the field of engineering. Results of the project include a more rigorous data collection and analysis process as well as systems for monitoring efforts to improve student achievement. These findings show how the E-APP, together with other integrated strategies, has made important advancements in the success of community college transfer students into undergraduate engineering programs.

Multiple evaluation results indicate that the E-APP has been successful in achieving its goals for implementation. Multiple early-outcome results also indicate that the E-APP is

achieving its overall goals. The E-APP results follow closely those of the university-wide APP program, which verify these findings. Past research also shows that partnership strategies increase success for community college transfers (Pascarella & Terenzini, 2005; Tinto, 1997). Although more time is needed to determine the sustainability of these increases and more data are needed to determine some of the measures of success, long-term positive outcomes of the E-APP are promising. The E-APP is an effective strategy that works best when integrated with other connection-based strategies, such as pre-engineering learning communities, engineering orientation courses offered at community colleges, and engineering advising. Both the E-APP and its integrated strategies show success in improving the transfer path for community college students in engineering.

Despite being in existence only for a short time, the E-APP is already showing significant improvements in retention rates of community college transfers to engineering. These data were analyzed given the low participation rates for the E-APP (32.9% at the CC, and 17.9% of all in-state community college transfers). As the information about this program and its integrated strategies continues to spread, it is expected that the participation and retention rates will continue to increase as SEEC and the E-APP move further into the outcome stages of project evaluation.

Findings show that increased participation in the E-APP at the community college level serves as a bridge for a smoother transition between the CC and the College of Engineering at the SU. Advisers and administrators at community colleges are adopting and promoting the E-APP as a result of communication between the institutions. Matriculation data for the E-APP participants are promising. Retention data at the SU show increased retention rates for the E-APP participants. The validity of these results has been tested by the

University-wide APP program, which shows a similar pattern of improved retention rates for the APP participants. The results are also validated by the University-level learning community data, which show increased success rates for students participating in learning communities (Laugerman, Rover, Bruning, Laanan, Mickelson, & Shelley, 2011).

The results of this study may be transferrable to other community colleges and universities. Implementation of some or all of the connection-based strategies will improve the ability of four-year institutions to promote and support the community college pathway as a viable, even attractive, route to a baccalaureate degree in engineering.

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CHAPTER 3. THE ROLE OF ACADEMIC INTEGRATION ON SUCCESS IN ENGINEERING FOR COMMUNITY COLLEGE TRANSFER STUDENTS

A paper submitted to the *Journal of Community College Research and Practice*

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Abstract

This paper provides needed data analysis between the community college and the university to determine effective strategies for increasing the success of community college transfer students in engineering. The impact of taking pre-requisite core engineering courses at a community college rather than a university is measured in terms of student integration. The goal is to understand the dynamics of persistence when transfer engineering students encounter the difficult-to-pass core-engineering courses. Descriptive and inferential statistics are employed to investigate the overall core-engineering grade point average as well as grades in calculus and physics and their ability to predict success in engineering. It will also examine the combination of calculus and physics at the community college that could indicate the best time for students to transfer. Results should interest anyone associated with community college students who wish to succeed in the pursuit of a professional engineering degree.

Nomenclature

Basic Program in Engineering

The Basic Program (BP) in engineering is a common set of core courses required of all engineering students at a large Midwest land grant state university (SU). All students must successfully complete this sequence with a minimum of a C average (2.0 on a 4.0 scale)

to graduate in engineering. This program consists of two semesters calculus, one semester of chemistry, one semester of physics, two semesters of English, one semester of engineering fundamentals with computer programming, a required course in engineering orientation, that is graded pass/fail, and a 0.5 credit course in library usage.

In this paper the overall BP grade-point average (GPA) will refer to the GPA in all these courses combined or in the portion of the courses that are completed at a particular institution. The specific calculus and physics courses will be referred to as; Calculus I, Calculus II, and Physics I.

Introduction

The path from a community college to an engineering degree can be filled with obstacles. In his commentary for the *Chronicle of Higher Education* Handel (2010) states: “What we [still] don’t know [about transfer students] is startling”. Few research studies have examined the perspective of community college graduates from accredited engineering programs. A better understanding of the behaviors of community college transfer students who succeed in engineering will assist researchers, policy makers and educators. It will also help guide short-term tactical and long-term strategic programming for transfer students in engineering. Understanding the variables that impact a student’s ability to deal with BP courses will allow for more targeted recruitment and focused intervention strategies to help students who are struggling with difficult courses. “If one were to accept the idea that success/failure in barrier courses determines the ultimate success of a student in engineering, understanding student experiences in barrier courses will offer us a unique and useful lens through which to view the phenomenon of attrition” (Suresh, 2006, p. 217).

Persistence in engineering is historically bound to performance in core-program courses which include: Calculus I, Calculus II, and Physics I (Budny, LeBold, & Bjedov, 1998; Levin & Wyckoff, 1990). “Among all challenging courses, mathematics seems to be the most difficult and hence the largest stumbling block causing dropouts in the freshman year in engineering schools” (Li et. al., 2009, p. 364). Specifically, student performance in the basic program courses is hypothesized to play a role in the success of community college transfer students in engineering. The goal of this study is to understand the dynamics of persistence when transfer engineering students encounter the difficult-to-pass BP courses. This study provides needed research about academic integration into engineering by measuring the impact of taking prerequisite BP courses at a community college as opposed to a university. It also compares success rates to those of a large group of students who enter the College of Engineering directly from high school.

Many studies measure academic integration using the first-year GPA without specifically examining grades earned in core engineering courses, commonly referred to in the literature a “gatekeeper” or ‘barrier’ courses” (Tyson, 2011). Since transfer students have less time for social integration to a university, academic integration is arguably one of the most important variables for the success of transfer students at a college of engineering.

This research examines the outcomes of a large group of community college transfers to the College of Engineering at SU. It measures levels of achievement in terms of grades in the critical BP courses (Calculus I, Calculus II, and Physics I), overall BP GPA, and credits transferred. It will show levels of these variables that statistically improve retention and graduation rates in engineering. It also compares this group of transfer students to those who enter the College of Engineering directly from high school, to determine where these groups

differ in academic achievement. The result is an estimation of the overall BP GPA necessary for transfer students to have equal graduation rates when compared with students entering directly from high school. Understanding this, students and advisors can pinpoint the grade achievement levels that are necessary and the appropriate timing of transfer to increase their likelihood of success.

The study adds to the body of research that Tyson (2011) finds largely absent, on engineering retention that examines the impact of taking prerequisite courses at a community college as opposed to a university. It is estimated that community colleges now educate about 44% of all undergraduates in the United States, (American Association of Community Colleges, 2011). Even though more high school graduates are choosing to attend community colleges to fulfill curriculum requirements, other first-year retention research in engineering omits community college attendance in their models of freshman engineering retention. This study takes advantage of the articulation agreement between in-state community colleges and SU (NSF STEP: STEM Student Enrollment and Engagement through Connections, SEEC), to track retention and graduation rates of students.

Background

Some research claims that community college transfers complete engineering degrees at the same rates as college students who enter directly from high school (Adelman, 1998). However, because of the Student Right-to-Know and Campus Security Act of 1990, community colleges are required to collect and report graduation and transfer rates. These data have resulted in some less-than encouraging statistics (The National Center for Higher Education Management Systems, 2009):

- Only 28% of first-time, full-time, associate degree-seeking community college students graduate with a certificate or an associate degree within three years.
- Fewer than half (45%) of students who enter community college with the goal of earning a degree or certificate have met their goal six years later.
- Slightly more than half (52%) of first-time, full-time college students in public community colleges return for their second year.

While all students do not enroll in community college for the purpose of attaining a degree, research has shown that the persistence patterns of those who intend to gain a degree or transfer are troubling and inconsistent (Driscoll, 2007).

A recent *Chronicle of Higher Education* report by staff of the Department of Education Statistics (2010) found statistically significant differences in the graduation rates for students who begin at community colleges from those who start at a four-year institution directly from high school. Based on a six-year longitudinal study of over 19,000 students, of those who started at 2-year public institutions, 46% had not received a certificate, associate's degree or bachelor's degree. This compares with only 24% of those who started at four-year institutions who had not received a degree after six years (Radford, Berkner, Wheelless, & Shepherd, 2010). Data analysis is a critical part of understanding this achievement gap and variables that influence student success, as measured by attainment of a bachelor's degree.

Levin and Wyckoff (1990) found that predictors of retention were dependent on the students' point of progress through the first two years of an engineering program. They used logistic regression to determine persistence at pre-enrollment, at the end of the freshman year and at the end of the sophomore year. The freshman year model identified the best predictors of retention as grades in Physics I, Calculus I, and Chemistry I. The sophomore year model

identified the best predictors of retention were grades in Calculus II, Physics I, and Physics II. Most of the students who leave engineering do so before they have successfully completed these difficult courses (Levin & Wyckoff, 1990). The first-year of college is particularly important because 35% of science, technology, engineering and mathematics (STEM) majors switch out of STEM fields after their first-year (Daempfle, 2002). Furthermore, data show that students must acquire proficiency in these key foundational areas to be able to succeed in engineering. In a longitudinal study of over 35,000 pre-engineering students at Purdue; 84% of those that left engineering did so before they completed their pre-professional program (Budny et al., 1998)

LeBold and Ward (1998) found that the freshman year is critical to retention and that the best predictors of retention were the first and second semester grades and the cumulative grade point average. They also found students' perceptions of their problem-solving abilities in mathematics and science to be significant predictors of retention. Budny et al. (1998) looked specifically at the effect of first-year course performance on graduation and found a strong correlation between first semester GPA and graduation rates in engineering.

Whalen and Shelley (2010) agree that the single fundamental variable in predicting retention in STEM-fields is GPA. They found that an average increase of as little as one-tenth of a percentage point in cumulative GPA significantly increased six-year retention and graduation rates of STEM majors. This suggests that effective interventions to improve student grades must be the top priority for retention of engineering students. Whalen and Shelley's (2010) research aligns with earlier research by Strenta, Elliot, Adair, Matier, and Scott (1994), which found that low grades were the most common predictor for all students leaving science and engineering courses. Schools have found that success strategies (such as

tutoring, supplemental instruction, and counseling) are effective in helping students complete these high risk courses (Budny et al., 1998; Shelley & Hensen, 2003).

Comments by Suresh (2006) also support this idea. “Performance in barrier courses often determines whether or not a student persists in engineering. At the very least, it causes some students to question their ability to make it through the program. While it is important that only students who can cope with the academic requirements of the program should continue in it, the challenge of barrier courses may cause otherwise able students to also transfer out.” (Suresh, 2006, p. 217).

Failing courses has a considerable, but difficult to measure, effect on student persistence in engineering, according to Suresh (2006). “It is hard to quantify the effect of failing a course on student persistence. At the minimum, it causes students to question if the degree they are seeking is right for them and perhaps if they could be successful in any degree program” (Suresh, 2006, p. 235). This was borne out in a recent retention analysis at Iowa State University, which found that community college transfers who left engineering also left the university at significantly higher rates than those that entered directly from high school (Laugerman, Rover, Bruning, Laanan, Mickelson, & Shelley, 2011).

Not all students who leave engineering do so because of bad grades; many students leave engineering in good academic standing (Zhang, Anderson, Ohland, Carter, & Thorndyke, 2004). Conversely, not all students who stay in engineering have good grades. Despite finding specific effects of academic achievement in prerequisite courses, Suresh (2006) also found that highly motivated students persist despite low achievement.

One reason for this persistence could be student perceptions and beliefs. Other research reports that freshman attitudes toward the engineering profession, perceptions about

the upcoming study program, and confidence levels about the ability to succeed in engineering affect retention (Besterfield-Sacre, Atman, & Shuman, 1997; Seymour, 2000). Students who leave engineering in good standing (as defined by a 2.0 or above GPA) have less appreciation of the engineering profession, differ in their mathematics and science interests, and have less confidence about their ability to succeed in engineering than do students who stayed in engineering. These students also tended to have more confidence in their communication skills than did those students who remained in the program (Besterfield-Sacre et al., 1997).

Pre-college characteristics account for a small but meaningful percentage of the variation in retention rates (Zhang et al., 2004). However, research shows that pre-engineering success factors are weaker predictors of retention in engineering than are grades in core engineering courses. Further, the combination of core engineering courses is a stronger predictor of success than any single course alone (Budny et al., 1998; Levin & Wyckoff, 1990).

This research builds on the work of Tyson (2011) and others by including community college grades; “a key element of academic and social integration that is unaccounted for in most studies of engineering retention” (Tyson, 2011 p. 763). Tinto (1993) defines academic integration as doing well in courses. Quantitative skills are a requirement for completing an engineering degree. Students with a C average or less have a high probability of leaving engineering (Veenstra, Dey, & Herrin, 2009; Zhang, Min, Ohland, & Anderson, 2006). This work examines academic variables that could address the probability of students leaving the field of engineering.

Suresh (2006) found that a majority of engineering majors either earned a low grade or dropped Calculus I, Calculus II, and Physics I strategic “gatekeeper” courses before leaving engineering.

Objectives

Based on the background research and the community college data available through the articulation agreement with in-state community college transfers to engineering, the objectives of this study are:

1. Determine levels of achievement in BP GPA for courses taken at the university that increase graduation rates.
2. Determine levels of achievement in BP GPA for courses transferred from the community college that increase graduation rates.
3. Determine levels of achievement in Calculus I, Calculus II and Physics I from both institutions that increase graduation rates.
4. Determine levels of achievement in Calculus I, Calculus II, and Physics I from both institutions that increase retention rates.
5. Determine the best time for transfer in terms of Calculus I, Calculus II, and Physics I.
6. Determine if community college transfer students from a 2002-2008 cohort come in with academic backgrounds that differ from those entering engineering directly from high school as measured by mathematics ACT scores (or equivalent mathematics SAT scores) and high school grade-point averages.

7. Determine if the graduation rates are equal between community college transfers and those beginning at the university (high-school admits), for those with equivalent university BP grade-point averages.

Research Design and Methodology

Using the SU's institutional research data, the records for all students who were admitted to the College of Engineering over a seven-year period from 2002 to 2008 (inclusive) were obtained. These data include longitudinal semester- by- semester academic and demographic data for 1,191 community college students who were admitted. Descriptive and inferential statistics were employed to investigate the ability of academic variables to predict success in engineering for this group of community college transfer students.

Students who started but left for a semester or more and returned to the college are included in this study. Students who did not start in engineering but later changed majors to the College of Engineering are not included because of the small number of students involved and the complication this added to the data analysis.

The Kaplan-Meier estimator (Kaplan & Meier, 1958) was used to create survival graphs representing retention in engineering based on course grades in Calculus I, Calculus II, and Physics I. Survival graphs are compared based on course grades to determine course break point grades where the survival-retention in engineering-is significantly improved.

For the graduation rate analysis, the Fall cohorts from 2002-2005 (inclusive) were used. This allowed sufficient time for these students to have graduated. This includes 472 in-state community college transfers to the College of Engineering. Any measureable academic variable that significantly improves graduation rates over the average graduation rate for this group is included in the study.

In this study, engineering retention or graduation measures success in the College of Engineering while university retention or graduation measures success at the university, which includes the College of Engineering.

Demographics

To ensure that the sample is representative of the population, the demographic data were compared between community college transfer students and direct from high school admits over the same period. Using a Pearson chi-square analysis, the results show that all admit groups had equal proportions of minority groups ($p= 0.01$) except for females. The proportion of female students is significantly less ($p<0.0001$) for the community college admits than for direct from high school admits to engineering. It is assumed that any subgroup of these students will have similar characteristics. The sample is large enough for the observations to be reliable and give sufficient power to the statistical tests (Levine, 2008).

Graduation Rates

These data were analyzed statistically to test for significant differences between groups. For categorical or binary variables, the Pearson chi-square analysis was used. In each test, the expected frequency assumption, which allows for the normal approximation to a binomial distribution, is met. This also assumes large populations and sampling without replacement. For numerical variables, the *t-test* for the equality of two means assuming equality of variance was used. The assumption of equality of variance between the groups was assessed using an *F-test* for the ratio of variances before the *t-test* for equal variance was used. For all significance tests, the resulting *p-value* (level of significance) is reported.

Retention Rates

The Kaplan–Meier estimator is the nonparametric maximum likelihood estimate of $S(t)$. It is a product of the form

$$\hat{S}(t) = \prod_{t_i < t} \frac{n_i - d_i}{n_i}.$$

When there is no censoring, n_i is the number of survivors just prior to time t_i . With censoring, n_i is the number of survivors less the number of losses (censored cases). It is only those surviving cases that are still being observed (have not yet been censored) that are "at risk" of not surviving.

A plot of the Kaplan–Meier estimate of the survival function is a series of horizontal steps of declining magnitude which, when a large enough sample is taken, approaches the true survival function for that population. The value of the survival function between successive distinct sampled observations is assumed to be constant.

An important advantage of the Kaplan–Meier curve is that the method can take into account some types of censored data, particularly *right-censoring*, which occurs if a student withdraws from a study or is lost from the sample before the final outcome is observed. Students who graduate are removed from the survival graphs over time and do not impact the percentage who failed to succeed.

Comparing survival curves

A common statistical test to compare survival curves is the generalized Wilcoxon , Breslow, and Gehan test (McGready, 2006). This test compares two survival curves across multiple time points to answer the question: Is there an overall survival difference between the groups? The null and alternative hypotheses are shown below:

$$H_0: S_1(t) = S_2(t)$$

$$H_a: S_1(t) \neq S_2(t)$$

The Wilcoxon, Breslow, and Gehan test is sensitive to early survival differences, which is consistent with finding variables that significantly influence retention in the two years after transfer. This computes the difference between what is observed at each event time and what would be expected under the null hypothesis. These differences are aggregated across all event times into one overall “distance” measure (i.e., how far sample curves differ from the presumed results in the null hypothesis after accounting for sampling variability). This test gives a *p-value* to indicate whether significant differences exist between the curves. A lower *p-value* indicates a more significant difference between the curves (McGready, 2006).

Conceptual Process Model

A conceptual process model is developed to illustrate the paths to an engineering degree that sets the stage for this analysis. Conceptual models provide a visual illustration of implicit and explicit assumptions on what actions are required to solve a problem and why the problem will respond to the actions (Chen, 2005). They also illustrate how the contextual factors and program activities are organized for implementing the intervention and supporting the change process (action model).

The conceptual model (Figure 1) illustrates the process a pre-college student follows on the path to an engineering degree. As illustrated by the conceptual model a pre-college student starts at either the community college or the university based on individual college choice factors which affect the college admission decision. The student can take the BP in engineering courses at either institution or a combination of both institutions. This results in

individual BP course grades from the community college and/or the university. It also results in an overall BP GPA from the community college and/or the university. In the model these are called transfer outcomes and university outcomes respectively. In either case, students must complete the BP with a 2.0 (C) average to enroll in the university engineering program. The final outcome is a degree in engineering, a degree in a non-engineering field or no degree.

Since transfer students have the option of taking some or all of their BP engineering courses at the community college and some or all of these courses at the four-year university, the graduation rates are separated by where a student took the BP course(s) and the overall GPAs they achieved in these course(s). The other group, based on admission status, is students who came to the university directly from high school (Figure 1).

The timing of the credits earned by the student determines the university classification for that student, either a transfer or direct from high school admit. A student entering during the semester directly following high school is considered a high school admit even if he or she brings “transfer credit” for dual-enrolled or advanced placement courses. Any credit transferred after high school graduation causes the student to be considered a transfer student to the university. An important point to note is that the community college listed as the transfer institution in this study is only the most recent institution attended, not necessarily the institution where the student had the most credits. It is not unusual for transfer students to have credit from multiple institutions (McCormick, 2003).

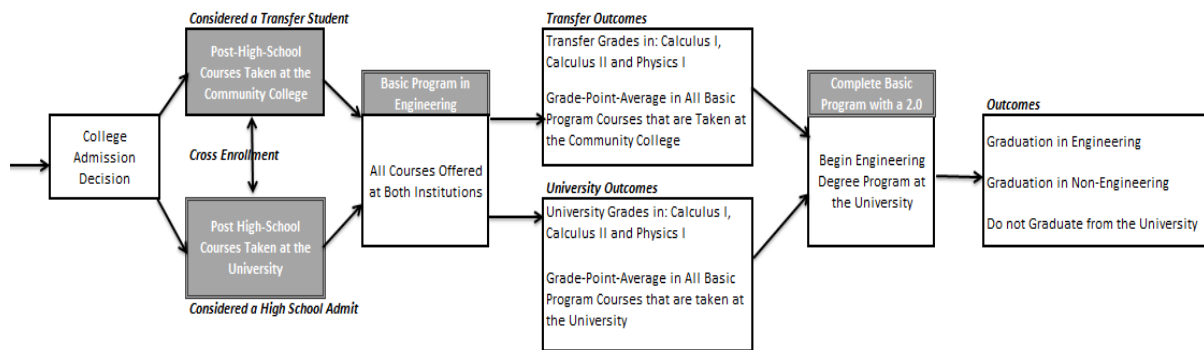


Figure 1. Conceptual process model

Results

Graduation Rates

The 472 community college students who transferred into the College of Engineering between 2002 and 2005 (inclusive) had a graduation rate in engineering of 49%. To give a perspective on this graduation rate, the graduation rates for other types of students that entered engineering between 2002 and 2005 are given in Table 1.

Table 1. Graduation rates for entering engineering students 2002-2005

Type of student	Graduated with a degree in ENGR	Graduated with a degree from SU	N
Iowa CC Transfer	49%	65%	472
Non-IA CC Transfer	59%	70%	121
Non-CC Transfer	61%	72%	317
High School Admit	53%	73%	4,220

Note from Figure 1 the difference between transfer outcomes and university outcomes. The results will be separated by transfer and university outcomes. Table 2 displays actual graduation rates in engineering by the GPA achieved in BP courses taken at the university (university outcomes). The grades represent the most recent one recorded for a student. Table 2 illustrates that a GPA of 3.0 or better in all BP courses taken at the university increases the graduation rate to 68%, which is a significant ($p < 0.05$) improvement over the average graduation rate of 49% for this same group.

To understand the graduation rate of 19% for students receiving a 1.0-2.0 GPA: it is possible for a student to get lower than a 2.0 grade in a single class (with the exception of an F grade) and still graduate in engineering as long as the overall BP GPA is 2.0.

Table 2. Actual graduation rates in engineering by university basic program grade point average

University Basic Program Grades		
GPA	Graduation Rate	n
less than 1.0 GPA	0%	40
1.0 - 2.0 GPA	19%	62
2.0 - 2.5 GPA	48%	60
2.5 - 3.0 GPA	53%	75
3.0 - 3.5 GPA	68%	73
3.5 - 4.0 GPA	82%	65

Note: Fall 2002-2005 in-state community college transfer students that took BP classes at the university

Table 3 shows actual graduation rates in engineering sorted by GPA in the BP courses transferred from the community college (transfer outcomes). This illustrates that a GPA of 3.5 or better in the BP courses transferred from the community college increases the graduation rate to 64%, which is a significant improvement over the overall graduation rate of 49% for community college transfers ($p < 0.05$). Because F grades are not transferred to the University, GPAs less than 1.0 are not recorded in the dataset.

Table 3. Actual graduation rates in engineering by transfer basic program grade point average

Transferred Basic Program Grades		
GPA	Graduation Rate	n
less than 1.0	-	-
1.0 - 2.0 GPA	0%	12
2.0 - 2.5 GPA	33%	67
2.5 - 3.0 GPA	50%	115
3.0 - 3.5 GPA	50%	139
3.5 - 4.0 GPA	64%	139

Note: Fall 2002-2005 in-state community college transfer students that transferred BP classes

Table 4 illustrates the effect of the Calculus I grade on graduation rate. The results are separated by the institution where the student took the course. Using the chi-square test to compare proportions, Table 4 shows that earning a 3.5 or better in Calculus I at the community college significantly ($p < 0.001$) increased graduation rates to 69%, which is above the overall rate of 49%. However, University Calculus I grades above a 3.5 do not significantly increase the graduation rates (67%) over the average. This is likely due to the smaller sample size for this group.

Table 4. Calculus I effects on graduation

Calculus I Grade Impact on Graduation in Engineering	% Earning a Degree in Engineering for Community College Transfers			
	Took Calculus I at University		Transferred Calculus I from Community College	
	Graduation Rates	n	Graduation Rates	n
1.0 - 2.0 GPA	7%	15	33%	6
2.0 - 2.5 GPA	32%	25	47%	99
2.5 - 3.0 GPA	56%	9	67%	21
3.0 - 3.5 GPA	56%	16	58%	76
3.5 - 4.0 GPA	67%	18	69%	132

Entered College of Engineering between 2002 and Fall 2005

Table 5 displays the effect of the Calculus II grade on graduation rate, separated by the institution where the student took the course. Using the chi-square test between proportions, Table 5 shows that earning a 3.0 or better in Calculus II at the university significantly ($p < 0.01$) increased graduation rates above the overall rate of 49%. However, Table 5 shows anomalies in the data for students who took Calculus II at the community college. All students who achieved a C or better had significantly higher graduation rates than overall ($p < 0.05$), but the highest graduation rates are recorded for students who earned a GPA of 2.5 to 3.0 in Calculus II.

Table 5. Calculus II effect on graduation

Calculus II Grade Impact on Graduation in Engineering	% Earning a Degree in Engineering for Community College Transfers			
	Took Calculus II at University		Transferred Calculus II from Community College	
	Graduation Rates	n	Graduation Rates	n
1.0 - 2.0 GPA	27%	15	31%	13
2.0 - 2.5 GPA	49%	41	57%	51
2.5 - 3.0 GPA	42%	12	81%	16
3.0 - 3.5 GPA	61%	28	63%	93
3.5 - 4.0 GPA	87%	15	73%	102

Note: entered College of Engineering between Fall 2002 and Fall 2005

Table 6 shows the effect of the Physics I grade on graduation rate, separated by the institution where the student took the course. The chi-square analysis determines that earning a 3.0 or better in Physics I at the university or earning a 3.5 or better at the CC significantly increases graduation rates above the overall rate of 49%.

Table 6. Physics I effect on graduation in engineering

Physics I Grade Impact on Graduation in Engineering	% Earning a Degree in Engineering for Community College Transfers			
	Took Physics I at University		Transferred Physics I from Community College	
	Graduation Rates	n	Graduation Rates	n
1.0 - 2.0 GPA	55%	49	38%	8
2.0 - 2.5 GPA	60%	40	62%	52
2.5 - 3.0 GPA	64%	11	64%	11
3.0 - 3.5 GPA	76%	41	63%	54
3.5 - 4.0 GPA	89%	19	78%	74

Entered College of Engineering between 2002 and Fall 2005

Retention Rates

The next part of the results focuses on retention rates instead of graduation rates for the group of 1,191 community college students who transferred to the College of Engineering

between 2002 and 2008 (inclusive). Two different survival graphs are included on each figure. Each shows the survival (or retention) in engineering for this group of community college students based on their grade in Calculus I, Calculus II, or Physics I. The results are separated by where a student took the BP course (transfer outcomes vs. university outcomes on Figure 1).

Calculus I

Figure 2 is a survival graph based on the Calculus I grade at the university. There are separate graphs for students obtaining a B (3.0) or better and for those students obtaining less than a B. It is at these break-points that the Wilcoxon test between the curves resulted in a statistically significant difference ($p < 0.001$) between the retention rates.

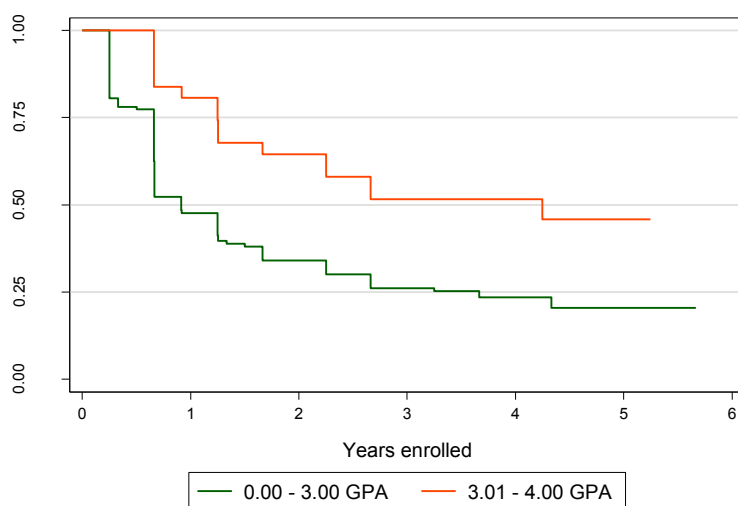


Figure 2. Survival rates for retention in engineering by Calculus I grade at the university

Figure 3 is a survival graph based on the Calculus I grade at the community college. There are separate graphs for students obtaining a B (3.0) or better and those students

obtaining less than a B. It is at these break-points that the Wilcoxon test between the curves resulted in a statistically significant difference ($p < 0.01$) between the retention rates.

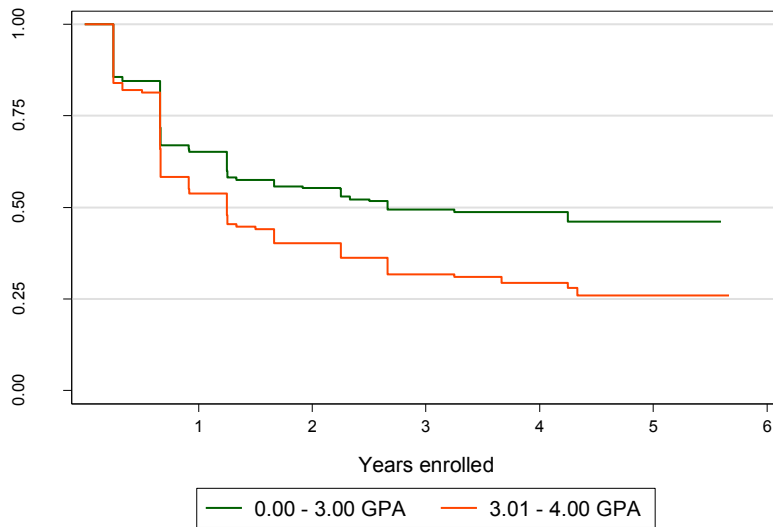


Figure 3. Survival rates for retention in engineering by transfer Calculus I grade

Calculus II

Figure 4 is a survival graph based on the Calculus II grade at the university. There are separate graphs for students obtaining a B (3.0) or better and those students obtaining less than a B. It is at these break-points that the Wilcoxon test between the curves resulted in a statistically significant difference ($p < 0.001$) between the retention rates.

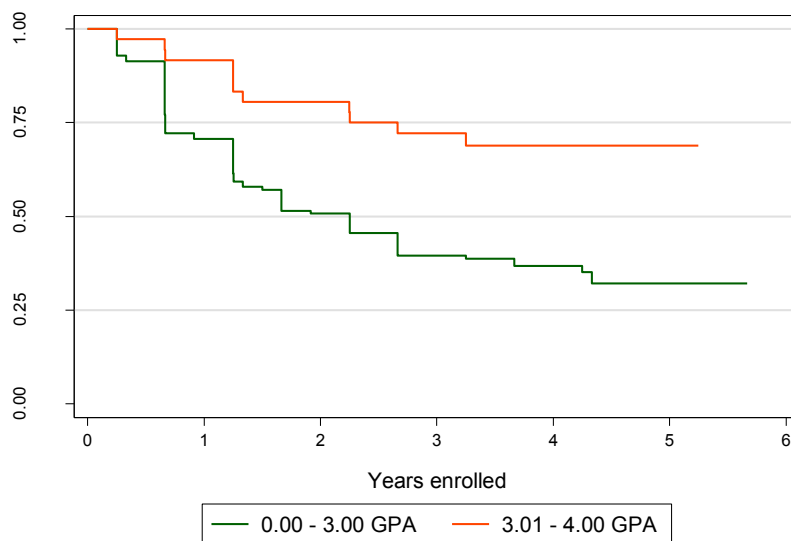


Figure 4. Survival rates for retention in engineering by university Calculus II grade

Figure 5 is a survival graph based on the Calculus II grade at the community college. There are separate graphs for students obtaining a B (3.0) or better and those students obtaining less than a B. It is at these break-points that the Wilcoxon test between the curves resulted in a statistically significant difference ($p < 0.05$) between the retention rates.

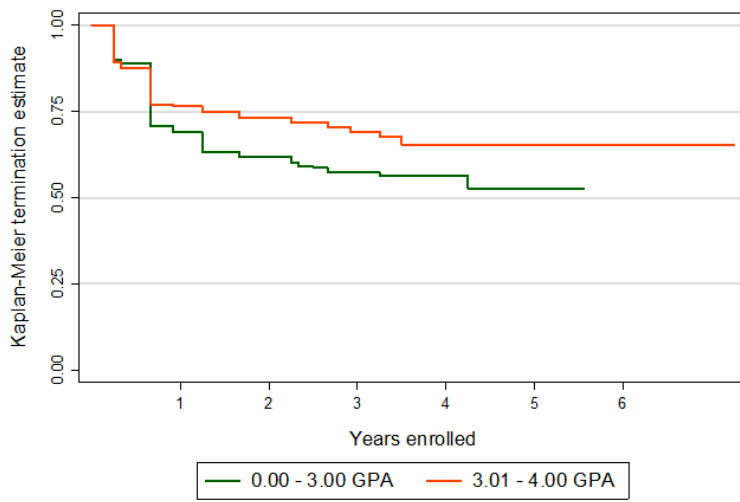


Figure 5. Survival rates for retention in engineering by transfer Calculus II grade

Physics I

Figure 6 is a survival graph based on the Physics I grade at the university. There are separate graphs for students obtaining a C (2.0) or better and those students obtaining less than a C. At these break-points the Wilcoxon test between the curves resulted in a statistically significant difference ($p < 0.0000$) between the retention rates.

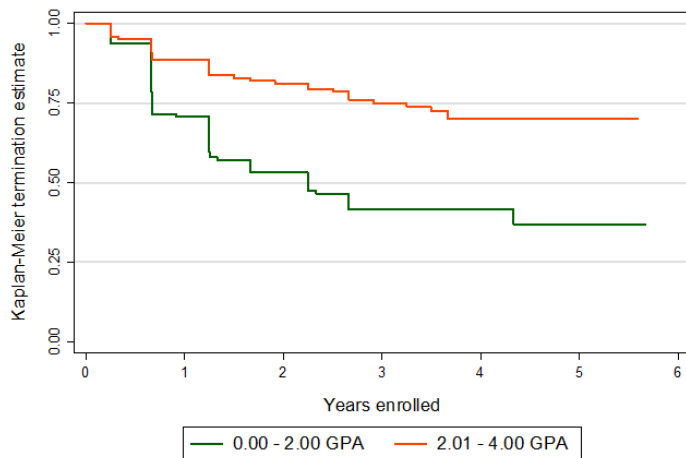


Figure 6. Survival rates for retention in engineering by university Physics I grade

Figure 7 is a survival graph based on the Physics I grade at the community college. There are separate graphs for students obtaining a C (2.0) or better and those students obtaining less than a C. At these break-points the Wilcoxon test between the curves did not show a statistically significant difference ($p=0.910$) between the retention rates.

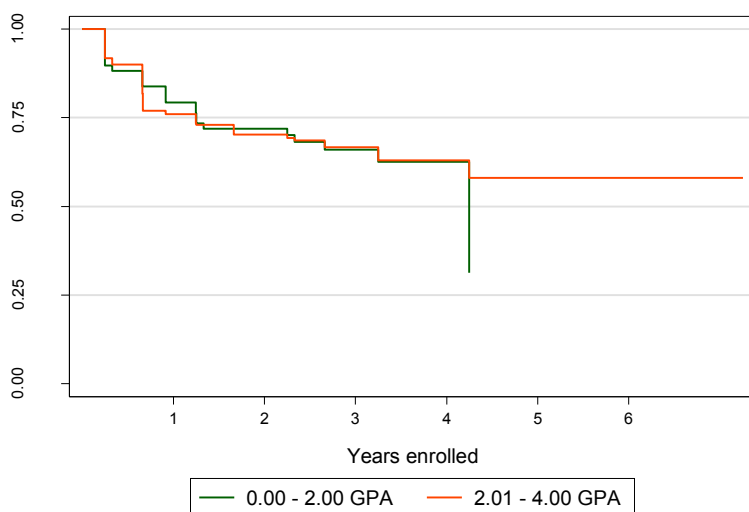


Figure 7. Survival rates for retention in engineering by transfer Physics I grade

Course Sequencing and Graduation Rates

Table 7 lists actual retention and graduation information for in-state community college transfers based on the sequence of courses taken at the community college. This is to determine how completion of Calculus I, Calculus II, and Physics I at the community college affects retention and graduation rates, which is the fifth objective of this study. The categories of course sequences in Table 7 are mutually exclusive.

Based on the empirical data for these cohorts in Table 7, community college transfer students who transfer the sequence of courses: (a) Calculus I, Calculus II, and Physics I or

(b) Calculus I and Calculus II from the community college have significantly higher graduation rates in engineering at $p < 0.05$. These groups have not been matched based on demographic characteristics due to missing data. However, mean mathematics ACT scores associated with each group are similar.

Table 7. Course sequencing for community college transfers

Community College Course Sequences Transferred to University	Engineering Retention after 1 year	Earned Engineering Degree	University Retention after 1 year	Earned University Degree	n	Average Math ACT Score
Calculus I, Calculus II & Physics I	77%	69%	88%	79%	166	25.2
Calculus I & Calculus II	72%	59%	84%	70%	82	26.3
Calculus I but not Calculus II	61%	34%	80%	63%	70	24.4
Neither Calculus I nor Calculus II	45%	25%	69%	49%	136	24.0

Notes: Entered College of Engineering between Fall 2002 and Fall 2005
 significant improvement for earned engineering degree at $p=0.05$ in bold

Academic Backgrounds

Table 8 shows the background characteristics by admit status to the College of Engineering. It compares background characteristics for the group of community college transfer admits to the College of Engineering with students admitted to the College of Engineering directly from high school over the same time period.

This table must be interpreted with caution, since the data include background characteristics for only 50% to 70% of the community college transfer students. Even considering this lack of complete data, it appears that this group of community college transfers come in with weaker academic backgrounds as measured by mathematics ACT scores (or equivalent mathematics SAT scores) and high school GPAs. Other research agrees with this finding. Tsapogas (2004, p.6) notes that GPAs tend to be lower for transfer students: “Science and engineering graduates with lower undergraduate grade point averages are more

likely to have attended community college than are graduates with higher grade point averages.” These lower GPAs may lead to lower grades in the engineering BP and lower retention and graduation rates.

Table 8. Background characteristics of students by admit status

Admission Type	N	University BP GPA		Math ACT Scores		High School GPA		CC Transfer GPA	
		Mean	n	Mean	n	Mean	n	Mean	n
Community College Transfer	1,191	2.32	830	25.0	650	3.24	585	3.08	1,183
High School Admit	10,511	2.71	8,997	28.0	9,849	3.63	10,441		

Note: significant differences ($p < 0.01$) in bold

Graduation Rate Comparisons

Table 9 makes a comparison between the community college transfers and direct from high school admits based on their overall GPA in BP courses taken at the university. The graduation rates of community college transfers are equal to those of high school admits with the same level of achievement in BP courses.

Table 9. Actual graduation rates in engineering by university basic program grade point average comparison

Percent Earning a Degree In Engineering by University Basic Program Grades				
Grade-Point Average	High School Admit	n	Community College Transfer	n
	less than 1.0	0%	184	0%
1.0 - 2.0	4%	419	19%	62
2.0 - 2.5	33%	706	48%	60
2.5 - 3.0	57%	999	53%	75
3.0 - 3.5	71%	1081	68%	73
3.5 - 4.0	79%	827	82%	65

Note: no significant difference between groups at grade point average > 2.5

If students are matched on GPA, there are no statistically significant differences between the groups above 2.5 GPA ($p < 0.05$). Therefore, community college transfers who can achieve GPAs similar to university BP GPAs have the same level of graduation rates as high school admits. These data answer the last objective of this study.

Conclusions and Recommendations

A number of internal, external, and demographic characteristics affect student retention in engineering. Among the external characteristics, the rigor of engineering curricula is cited as one of the most important variables contributing to student attrition, with calculus being the largest obstacle (Li, Swaminathan, & Tang, 2009). If grades in BP courses represent a command of the subject areas that are necessary to succeed in engineering, the results of this research provide a plan for engineering success for community college transfer students.

This research is based on the conceptual process model in Figure 1, where the outcomes for a pre-college student are separated by transfer outcomes and university outcomes.

Conclusions based on objectives of this study

A number of conclusions are based on the stated objectives of this study. Objectives 1-3 are based on the graduation rates in engineering for the group of in-state community college transfers from Fall 2002 through Fall 2005. The overall recommendation based on these findings is to earn a B (3.0) or better in all the BP courses taken at the university. Students who transfer these courses from a community college should attain a B+/A- (3.5) in all BP courses taken at the CC. These recommendations, if implemented, have the potential

to significantly increase the graduation rate in engineering above the overall graduation rate of 49% for this group of CC transfer students.

Objective 4 is based on retention in engineering for a larger group of community college transfer students. Retention is measured by survival graphs at different break-points in GPA for courses including Calculus I, Calculus II, and Physics I. Survival charts show a more “real time” picture of retention and include data for students entering engineering between 2002 through 2008. The survival charts indicate that a 3.0 (B) in Calculus I and Calculus II at either institution significantly increases retention rates over students earning less than a B. A Physics I grade of C (2.0) at the university significantly increased retention rates over students earning less than a C. The Physics I grade at the community college did not significantly increase the retention rates.

Objective 5 is based on the sequence of transfer credits that maximize the graduation rates in engineering for community college transfer students. Based on this sample, students who transfer the sequence of courses including: (a): Calculus I, Calculus II, and Physics I or (b) Calculus I and Calculus II at the community college have a higher success rates than those who do not transfer as many of these courses into the university.

Objective 6 is to make a comparison of background characteristics that are available for this group of community college transfer students and from students who enter engineering directly from high school. For the 2002-2008 cohorts of students, based on the data available, community college transfer students enter the university with a weaker academic background than those who enter engineering directly from high school as measured by mathematics ACT scores (or equivalent mathematics SAT scores) and high school grade-point averages.

The last objective is to measure graduation rates based on the overall GPA in BP courses taken at the university. Graduation rates between community college transfer students to engineering and students entering engineering directly from high school are equivalent for students with similar university BP GPAs.

This study found that for community college transfer students to have the best chance of graduating with an engineering degree, they need to focus on being successful in the Basic Program courses, either at the community college before they transfer or after they transfer to the university. It is advantageous in terms of success rates to take: (a) Calculus I, Calculus II, and Physics I or (b) Calculus I and II at the community college before transferring. Particular focus should be on realizing success in Calculus I and Calculus II by earning a 3.0 GPA or better. Overall, community college transfers can graduate at the same rate as those entering the university directly from high school if they have similar Basic Program GPAs.

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CHAPTER 4. PREDICTING GRADUATION RATES IN ENGINEERING FOR COMMUNITY COLLEGE TRANSFER STUDENTS

A paper to be submitted to the *Journal of Applied Research in the Community College*

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Abstract

This paper reports on the research strategy of using boosted logistic regression models to predict success in engineering for community college transfer students. The models are developed based on academic and demographic variables for in-state community college (CC) transfer students who entered the College of Engineering at a large Midwestern State University. It follows them longitudinally over a six-year period to determine what academic integration characteristics predict success in engineering. This includes academic variables measured at both the community college and the University while controlling for background characteristics. The emphasis of each model is to develop a useful strategy for advising students that will increase success rates in engineering. Any data-driven success strategies that can be offered to these students are inherently timely and vital.

Boosted logistic regression is a relatively new strategy used in retention research to improve model fit over traditional logistic regression models. In this study it is used to determine which academic variables exert the greatest influence on predicting graduation in engineering. Three models are developed based on research showing the most likely times for students to leave engineering. The model-fit statistics are analyzed using pseudo r -squared, mean square error, and root mean square error values.

The overall model for this research is able to explain over 35% of the variation in graduation rates with a parsimonious number of academic variables. Since causality cannot be determined from retrospective data, this research implies a correlation between the highest-influence variables it discovers, and recommends levels of academic achievement for these variables.

Consistently high-effect variables are the first fall and first-year grade point averages (GPAs) at the University after transfer as well as the number of credits transferred from the CC that apply to the core program in engineering. Conclusive recommendations are developed to increase the success of CC transfers to engineering and ultimately increase the number and diversity of the engineering population.

Introduction

This paper reports on the research strategy of using boosted logistic regression models to predict success in engineering for community college (CC) transfer students. The models are developed based on academic and demographic variables for in-state CC transfer students who entered the College of Engineering at a large Midwestern State University (University). It follows transfer students longitudinally over a six-year period to determine what academic integration characteristics contribute to their success in engineering. This includes academic variables measured at both the CC and the University while controlling for background characteristics. These variables then are used to create predictive models for success early in the university career that allow for timely intervention strategies. The emphasis of each model is to develop a useful strategy for advising students, based on

success variables, which will have greater potential to increase success rates for transfer students in engineering.

To determine which academic variables exert the most significant effects on graduation, this study uses a boosted logistic regression technique. Boosted regression is used for the reduction of academic prediction variables to determine those which exert the most influence on the response variable, which in this case is graduation in engineering. The technique was developed in the artificial intelligence industry and is most frequently associated with data-mining (Hastie, Tibshirani, & Friedman 2001; Schonlau, 2005). The boosted regression logic is a relatively new strategy for retention and graduation rate research, but has shown success over traditional logistic regression models in prediction accuracy (Hastie, Tibshirani, & Friedman 2001; Schonlau, 2005). In addition to increased predictive accuracy, the results of boosted regression are intuitively easier to understand. This allows professionals providing academic advice to focus on the most important or influential variables. It reports on the percentage influence of each variable instead of the regression coefficients as reported in logistic regression or traditional least squares regression to summarize the predictor variables' effects.

One problem in creating these models is determining which of the many academic prediction variables to include. In this study core-course offerings (called the Basic Program [BP] in engineering) are examined in detail since they have been shown to have the most predictive accuracy in relevant research (Budny, LeBold, & Bjedov, 1998; Levin & Wyckoff, 1990; Tyson, 2011). The BP is a common set of courses required of all engineering students at the university. All students must successfully complete the BP with a minimum C average (2.0 on a 4.0 scale) to graduate in engineering. This program consists of two semesters of

calculus, one semester of chemistry, one semester of physics, two semesters of English, and one semester of engineering fundamentals with computer programming. The academic variables that exert the most influence on graduation in engineering, as well as the achievement levels in Calculus I, Calculus II, Physics I, and Chemistry I that predict success, are presented. These courses represent the most substantial barrier to achieving an engineering degree (Levin & Wyckoff, 1990).

Unique in this study is the use of academic variables from the CC. Other models based on academic integration variables have not included CC characteristics (Tyson, 2011). Nor have they been specific to graduation in engineering for CC transfer students. This research implies a correlation between the highest-influence variables it discovers, and recommends levels of academic achievement for success since causality cannot be determined from retrospective data. Taken together, these strategies provide a roadmap for success that proved influential for the sample dataset of students. Any data-driven success strategies that can be offered to these students are inherently timely and vital.

Boosted regression models are developed for transfer students after the first fall semester and the first-year at the University, historical points where a student is most likely to leave engineering (Budny, et al., 1998; LeBold & Ward, 1998; Levin & Wyckoff, 1990). An overall model is developed which includes grades in all the BP courses that may be taken the second or third year, depending on the student's timing through the coursework.

In combination with other non-quantitative research strategies, this research will provide one more tool for the two-year transfer student in the process of attaining an engineering degree. This research could further increase the number and diversity of engineering graduates.

Background

There has been a recent firestorm of students turning to CCs for educational and professional advancement (American Association of Community Colleges, 2011; Baime, 2011; Mullin, 2011). According to the American Association of Community Colleges (AACC), CCs provide a local, affordable, and low-risk path to development and expansion of marketable skills (AACC, 2009). The trend is especially strong for traditionally under-represented populations: women, minorities, rural students, veterans, and older Americans (AACC, 2011). These groups are becoming increasingly central to the United States mission to graduate more scientists and engineers (National Science Board, 2010). However, many of these potential scientists and engineers leave this pathway before completing a four-year degree (National Research Council, 2005).

CC transfer students are difficult to analyze as a group because of their very non-homogenous nature. Furthermore, understanding and addressing persistence at the CC level is a multi-faceted task that takes into account fluctuating state funds and a diverse service population (Bailey & Alfonso, 2005). In addition, the enrollment patterns of CC students are complex and may involve multiple transfers across multiple institutions (McCormick, 2003). However, the academic requirements in engineering for all CC students form a common ground for analysis.

Previous research suggests that point-of-progress models based on academic variables are a key aspect in determining retention and graduation in engineering. Levin and Wyckoff (1990) noted that predictors of retention were dependent on the students' point of progress through the first two years of an engineering program. They used logistic regression to determine persistence at pre-enrollment, at the end of the freshman year, and at the end of the

sophomore year. The freshman year model identified the best predictors of retention as grades in Physics I, Calculus I, and Chemistry I. The sophomore year model identified the best predictors of retention were grades in Calculus II, Physics I, and Physics II.

Most of the students who leave engineering do so before they have successfully completed these difficult courses (Levin & Wyckoff, 1990). Data show that students must acquire proficiency in these key foundational areas to succeed in engineering. In a longitudinal study of over 35,000 pre-engineering students at Purdue, 84% of those who leave engineering did so before they completed their pre-professional program (Budny, LeBold & Bjedov, 1998).

LeBold and Ward (1998) also found that the freshman year is critical to retention and that the best predictors of retention were the first and second semester grades and cumulative GPA. They found that students' perceptions of their problem-solving abilities in mathematics and science were also predictive of retention. Budny et al. (1998) looked specifically at the effect of first-year course performance on graduation and found a strong correlation between first-semester GPA and graduation rates in engineering.

Other researchers have also found that the single fundamental variable predicting retention in science, technology, engineering, and mathematics (STEM) fields is grade point average (Whalen & Shelley, 2010). They found a dramatic increase on six-year retention and graduation rates for as little as a 0.10 increase in GPA for STEM majors. This suggests targeted interventions to improve grades must be the top priority for retention of engineering students. Earlier research by Strenta, Elliot, Adair, Matier, and Scott (1994) found that low grades were the most common predictor for all students leaving science and engineering courses. Schools have found that success strategies such as tutoring, supplemental instruction

and counseling are effective in helping students complete these high risk courses (Budny et al., 1998; Shelley & Hensen, 2003).

Pre-college characteristics account for a small but meaningful percentage of variation in retention rates (Zhang, Anderson, Ohland, Carter, & Thorndyke, 2004). However, research shows that pre-engineering success measures are weaker predictors of retention in engineering than are grades in core engineering courses (Budny et al., 1998; Levin & Wyckoff, 1990). Further, the combination of first-year course grades is a stronger predictor of success than the grade in any single course.

Multiple data analysis methods have been applied to predict retention and graduation rates by using academic and demographic variables. Conventional predictive models have used logistic regression. Other data analysis methods existing in the literature are summarized by Li, Swaminathan, and Tang (2009):

- Stepwise/Hierarchical Multiple Regression:
- Longitudinal Data Analysis
- Covariate Adjustment
- Two-Step Design
- Exploratory Factor Analysis:
- Structural Equation Modeling
- Discriminant Analysis
- Classification Tree

This research utilizes logistic regression, multiple linear regression, and longitudinal data analysis, but includes a newer boost algorithm that includes CC variables. Boosted regression is a data-mining technique that has shown considerable success in predictive accuracy

(Schonlau, 2005) over traditional logistic regression models. In combination with other quantitative research strategies, this will provide one more tool for the two-year transfer student in the process of attaining an engineering degree. This could further increase the number and diversity of engineering graduates.

Objectives

The objectives of this study are to:

1. Develop boosted logistic regression models using academic and demographic variables to predict graduation rates in engineering for CC transfer students at the end of the first semester and at the end of the first-year after transfer.
2. Develop an overall boosted logistic regression model using academic and demographic variables to that is descriptive of graduation in engineering for CC transfer student once a student has completed the BP.
3. Determine the model fit statistics for these models by comparing them to actual graduation rates.
4. Report on the levels of achievement for academic variables that maximize success in engineering.

Research Design and Methodology

Using the university's institutional research data, the records for all CC transfer students who were admitted to the College of Engineering in the fall semester from 2002 to 2008 (inclusive) were obtained. The graduation analysis uses 472 of these CC transfer students who were admitted to the College of Engineering from 2002-2005. This group is selected to provide sufficient time for graduation in engineering. Since only fall semester entries for each year were included in the dataset, it is assumed to be a representative sample

of the CC transfer students who enter in spring and summer semesters. The data did not depart from this assumption.

This study includes students who dropped out or stopped out and returned to the University, but does not track the students who left and did not return in the six-year time period. Some of these students undoubtedly were successful in obtaining a certificate or degree from another institution, but there is no way of tracking those students. Students who did not start in engineering but later changed majors to the College of Engineering were not included because of the small number of students involved and the complication these data would have added to the research.

The academic variables included in the study are: GPAs in BP courses at the University, CC transfer GPAs in BP courses, the total number of CC BP transfer credits, the first fall, first spring, and first-year GPA at the University, and the number of credits the first fall, first spring, and first-year at the University. Since a community college student has the option of transferring some or all of the BP courses, the BP course grades are included from both the CC and the University.

CC grades can provide a missing piece of the puzzle in graduation and retention research (Tyson, 2011). Introducing CC course grades increases the variability, so results that include grades from CC courses are separated from results that include grades in courses taken at the University. It is assumed that the groups of CC students taking the courses at either institution are equivalent. No statistical information was found to refute this. Variability of course grades is always a concern as no two courses or instructors are alike. In addition grades may create problems of measurement error. Large sample sizes can reduce this overall variability somewhat.

The background variables included are: gender, ethnicity and learning community participation. Other typical demographic variables have too many missing values to include in the study. For example CC transfer students are not required to include ACT or SAT test information and high school rank is also frequently missing.

It is assumed that the academic and background variables for the groups of fall cohorts entering engineering from 2002-2005 represent random, independent, normally distributed samples. The sample sizes and Central Limit Theorem help to validate the normality assumption. Density function graphs are examined for each high-effect exogenous variable, with no major departures from normality observed except for a slight left skew, which is expected in GPA measures.

Boosted logistic regression is used to determine which academic variables exert the greatest influence on predicting graduation in engineering, while controlling for background variables. Three models are developed based on research showing the most likely times for students to leave engineering; after the first semester at the university, after the first-year at the university, and before completion of the BP in engineering (Budny, et al., 1998; Levin & Wyckoff, 1990). For a transfer student, the completion of the BP may actually occur before transfer. In the case of a student needing remediation in mathematics, the completion of the BP may not happen until after the second year or later at the University. By the time a student completes the BP with a GPA of 2.0 or higher (on a 4.0 scale), most of the attrition in engineering may have occurred. This makes the overall BP model of retention somewhat deterministic instead of purely probabilistic.

This research uses the Stata data analysis package. Stata is a general-purpose statistical software package created in 1985 by StataCorp. The “boost” command within

Stata starts the boosting algorithm described in Hastie, Tibshirani, and Friedman (2001) to develop three models that predict graduation in engineering. Each model shows the academic variables having the highest-influence on graduating in engineering for this group of CC transfer students. A strength of the boosting algorithm is that interactions and nonlinearities need not be explicitly specified. Another strength is that categorical variables do not need to be transformed (Hastie, Tibshirani, & Friedman, 2001). However, missing values do create problems for boosted regression and must be dropped from the analysis. In this analysis, a loss of less than 9% of the dataset occurred.

With this technique, correlated data can turn up in the model; such as using the first-semester GPA, the second-semester GPA and the first-year GPA. The mean-square error (MSE) term incorporates the error for each exogenous variable, including correlated variables, thus taking into account the additional error from correlated terms. Also, the separation of training data and test data helps guard against over-fitting that may arise in the context of correlated data. All of the variables in the final models are tested for collinearity using the variance inflation factor (VIF). Generally, VIF statistics less than 5 are considered acceptable (Levine, 2008). Therefore no highly correlated variables are included in the final models.

The boost command determines the number of iterations that maximize the likelihood, or, equivalently, the pseudo-r-squared values. Pseudo-r-squared values are computed for both the trained and the test data within the model. The trained model contains 80% of the dataset and the test model contains the other 20% of the dataset. These percentages were varied to see the effect on the pseudo- r-squared values. No statistical reason was found to change these percentages.

The pseudo-r-squared values illustrate how much of the variation in graduation rates is explained by variation of the prediction variables in the model. The pseudo-r-squared is defined as $r\text{-squared} = 1 - L1/L0$, where $L1$ and $L0$ are the log likelihood of the full model and intercept-only model, respectively. Unlike the coefficient of determination, R -squared, value given in least squares regression, the pseudo-r-squared value is an out-of-sample statistic (the smaller percentage of the population, generally 20%). Out-of-sample r -squares tend to be lower than in-sample- r -squares, which is the case in this study. The reason $1 - L1/L0$ is called pseudo-r-squared is that its formula resembles the coefficient of determination, R -squared, which is equal to $1 - SSE/SST$, where SSE is the sum of the squares due to error (unexplained variation) and SST is the total sum of squares (explained plus unexplained variation). Larger R -squared (or pseudo-r-squared) values indicate better fit of the model, meaning the amount of unexplained error is small. For that to happen, the ratio $L1/L0$ needs to be small, which means $L1$ needs to be much smaller than $L0$. This implies that the full model is better than the null model (similar to having a model with small SSE) (Agresti & Finlay, 2009).

Once the models are determined, the model-fit statistics are analyzed using pseudo-r-squared values of the training and test data, the MSE values, and the root mean square values (RMSE). MSE values show the amount of variation in the chi-square goodness of fit test statistic that is accounted for in the model and RMSE values determine the extent to which the estimated model differs from the actual on average.

Graduation rates tables are created to compare the predicted and actual graduation rates with levels of achievement for the highest-effect variables. The idea is to create recommended thresholds of achievement based on this group of CC transfer students. There

was a naturally occurring break in the graduation rates above 40% and again above 70%. The levels of achievement for the highest-effect variables are measured at these graduation rates resulting in recommended thresholds of achievement.

Results

Data available at the end of the first semester

Table 1 displays the variables available at the end of the first semester that exert the most influence on graduation in engineering for CC transfer students. These variables are: the first fall (University) GPA, total number of BP transfer credit hours, CC BP transfer GPA, and number of first fall credits completed at the university. Together these account for 93.2% of the variable influence on earning an engineering degree.

Table 1. One-semester model: Variable influence factors for highest-effect variables

Fall 2002-Fall 2005 CC Transfer Admits	% Influence on Earned Engineering Degree*
First Fall GPA	42.3%
CC BP transfer credit hours	25.9%
CC BP transfer GPA	12.8%
First Fall credits completed	12.2%
University Calculus II credit	3.2%
Entry year	1.4%
Total	97.8%

*Note: total percentage influence is 100%-some low percentage variables are omitted

Table 2 compares the boosted model predictions in 0.20 increments to the actual graduation rates in engineering including the levels of high-influence variables. This table illustrates how the predicted probabilities compare to the actual rates of earning an engineering degree. It shows how the model over-predicts graduation rates at lower levels. Of special note are the small differences in parameter values between the 66% and the 94%

actual graduation rates, suggesting that there is a big difference in graduation rates even with small increases in high-influence variables. For the highest-influence variable this is the difference between a 2.62 and a 3.08 University first fall GPA.

Table 2. Model comparison of graduation probabilities by highest-effect parameters at the end of the first semester in 20% increments

Predicted Probability of Earned Engineering Degree, After 1st Semester	Actual Rate of Earned Engineering Degree	CC BP Transfer GPA	University First Fall GPA	University First Fall Credit Hours Completed	Number of BP Transfer Credits	N
10% - 20%	1%	2.78	1.17	10.3	9.7	103
20% - 40%	15%	2.92	2.03	12.4	12.7	74
40% - 60%	55%	2.95	2.24	11.5	15.6	44
60% - 80%	66%	3.13	2.62	12.2	17.7	73
80% - 100%	94%	3.43	3.08	13.9	20.7	152
Average	51%	3.10	2.31	12.3	15.9	446

Table 3 reduces the graduation rates from Table 2 into three naturally occurring categories. The table is useful for recommending thresholds of achievement for high- effect variables at this point of progress toward an engineering degree. In order of the highest-effect variables, a CC transfer student should strive to achieve a 2.99 or above university first fall GPA, transfer at least 20.2 credits toward BP courses, have a CC transfer GPA in BP courses of at least 3.4, and complete at least 13.5 credits the first fall at the university. For students who met all of these targets, the result was a 90% or better probability of graduating in engineering. This is a significant improvement over the overall graduation rate of 51%. The

table also shows how the model could be under-predicting the graduation rates at higher levels.

Table 3. Model comparison of graduation probabilities by highest-effect parameters at the end of the first semester in 30% increments

Predicted Probability of Earned Engineering Degree, After 1st Semester	Actual Rate of Earned Engineering Degree	CC BP Transfer GPA	University First Fall GPA	University First Fall Credit Hours Completed	Number of BP Transfer Credits	N
10% - 40%	11%	2.84	1.53	11.2	10.9	177
40% - 70%	50%	2.97	2.40	11.8	16.4	78
70% - 100%	90%	3.40	2.99	13.5	20.2	191
Average	51%	3.10	2.31	12.3	15.9	446

Table 4 shows the variance inflation factor (VIF) values for all of the variables.

Based on the VIFs the variables have low or no collinearity (redundancy).

Table 4. First-semester variance inflation factor values

Variable	VIF
Number of BP transfer credits	2.12
University Calculus I credit	1.82
First Fall GPA	1.43
University Calculus II credit	1.37
CC BP Transfer GPA	1.37
First Fall credits completed	1.09
Female	1.07
Number of learning communities	1.06
Admit year	1.04

Note: A value less than 5 indicates low or no collinearity

Data available at the end of the first-year

At the end of the first-year, more information is available about the CC transfer students and therefore more exogenous variables are needed to determine which predictors

have a high-influence on graduation. There is also a decrease in the number of students left in engineering, from 446 at the end of the first semester to 418 at the end of the first-year. It is expected that this model will predict graduation in engineering better than the one-semester model. Looking at Table 5, with the variables in order of highest to lowest level of influence, it is clear that the CC academic experience and the first-year at the University still play important roles in the graduation rate. Together the five variables account for 93.9% of the influence on earning an engineering degree.

Table 5. One-year model: Variable influence factors for highest-effect variables

Fall 2002-Fall 2005 CC Transfer Admits	% Influence on Earned Engineering Degree*
First year GPA	45.9%
CC BP transfer credit hours	19.4%
First Fall credits completed	10.8%
First Fall GPA	9.1%
CC BP transfer GPA	8.7%
University Calculus II credit	1.9%
University Calculus I credit	1.4%
Total	97.2%

*Note: total percentage influence is 100%-some low percentage variables are omitted

Table 6 compares the boosted model predictions in 0.20 increments to the actual graduation rates in engineering including the levels of high-influence variables. This table illustrates how the predicted probabilities compare to the actual rates of earning an engineering degree. The table also shows how the model over-predicts graduation rates at lower levels. Of special note are the small differences in parameter values between the 73% and the 94% actual graduation rates, suggesting that there is a big difference in graduation rates even with small increases in high-influence variables. For the highest-influence variable, this equates to a difference between a 2.69 and a 3.13 University first-year GPA.

Table 6. Model comparison of graduation probabilities by highest-effect parameters at the end of the first-year in 20% increments

Predicted Probability of Earned Engineering Degree, After 1 Year	Actual Rate of Earned Engineering Degree	CC BP Transfer GPA	University First Fall GPA	University First Year GPA	University First Fall Credit Hours Completed	Transferred BP Credits	N
10% - 20%	0%	2.78	1.44	1.47	11.5	10.2	108
20% - 40%	19%	2.81	1.92	2.13	12.2	14.9	47
40% - 60%	46%	3.05	2.28	2.40	11.8	17.5	39
60% - 80%	73%	3.05	2.45	2.69	12.3	17.1	63
80% - 100%	94%	3.43	3.10	3.13	13.5	19.9	161
Average	54%	3.10	2.36	2.45	12.5	16.2	418

Table 7 reduces the graduation rates from Table 7 into three naturally occurring categories. This table is useful for recommending thresholds of achievement in high-effect variables at this point of progress toward an engineering degree. In order of the highest-effect variables, a CC transfer student should strive to achieve a 3.06 or above University first-year GPA, transfer at least 19.3 credits toward BP courses, complete at least 13.31 first fall credit hours, have a first fall GPA of 2.99 or better, and have a CC transfer GPA in BP courses of at least 3.36. For students who met these benchmarks, their probability of graduating in engineering increased to over 92%. This level is a significant improvement over the overall graduation rate of 54%. The table also shows how the model may be under-predicting the graduation rates at higher levels.

Table 7. Model comparison of graduation probabilities by highest-effect parameters at the end of the first-year in 30% increments

Predicted Probability of Earned Engineering Degree, After 1st year	Actual Rate of Earned Engineering Degree	CC BP Transfer GPA	University First Fall GPA	University First Year GPA	University First Fall Credit Hours Completed	Number of BP Transfer Credits	N
10% - 40%	6%	2.79	1.59	1.67	11.73	11.65	155
40% - 70%	52%	3.06	2.33	2.49	11.81	17.60	67
70% - 100%	92%	3.36	2.99	3.06	13.31	19.33	196
Average	54%	3.10	2.36	2.45	12.48	16.21	418

Table 8 shows the variance inflation factor (VIF) values for all of the variables.

Based on the VIFs the variables have low or no collinearity (redundancy).

Table 8. One-year variance inflation factor values

Variable	VIF
First Fall GPA	3.46
First year GPA	3.44
Number of BP transfer credits	2.24
University Calculus I credit	1.89
University Calculus II credit	1.47
CC BP Transfer GPA	1.47
First year credits completed	1.16
Female	1.07
Number of learning communities	1.05
Admit year	1.03

Note: A value less than 5 indicates low or no collinearity

Overall Model

The overall model is determined at the point when a student has completed the BP courses. Since this may occur later than after the first-year at the University, this model may be more deterministic than probabilistic. The top four highest-influence variables in the overall model (Table 9) are the same as for the one-year model (Table 5), which reiterates the

importance of these variables in predicting graduation in engineering. Table 9 shows that the first-year GPA exerts 39.5% of the influence (of the variables) on graduation in engineering, while the total CC BP credit hours transferred exerts 22.0% influence on graduation in engineering. Unlike the one-year model, the overall model includes more variables in the highest-effect parameters because more information is known at this point of progress toward an engineering degree. The model fit statistics are also improved over the one-year model (Table 13).

Table 9. Overall model: Variable influence factors for highest-effect variables

Fall 2002-Fall 2005 CC Transfer Admits	% Influence on Earned Engineering Degree*
First year GPA	39.5%
CC BP transfer credit hours	22.0%
First Fall credits completed	7.2%
First Fall GPA	6.0%
CC BP transfer GPA	5.4%
First year credits completed	4.0%
University Physics I credit	3.4%
University Calculus I credit	1.4%
Total	88.9%

*Note: total percentage influence is 100%-some low percentage variables are omitted

Table 10 compares the boosted model predictions in 0.20 increments to the actual graduation rates in engineering including the levels of high-influence variables. This table illustrates how the predicted probabilities compare to the actual rates of earning an engineering degree. It shows how the model over-predicts graduation rates at lower levels. Especially noteworthy are the small differences in parameter values between the 77% and the 98% actual graduation rates, suggesting there is a big difference in graduation rates even for

small increases in high-influence variables. For the highest-influence variable, this would mean the difference between a 2.74 and a 3.09 university first-year GPA.

Table 10. Overall model comparison of graduation probabilities by highest-effect parameters in 20% increments

Predicted Probability of Earned Engineering Degree, Overall Model	Actual Rate of Earned Engineering Degree	CC BP Transfer GPA	University First Fall GPA	University First Year GPA	University First Fall Credit Hours Completed	Number of BP Transfer Credits	N
10% - 20%	2%	2.82	1.54	1.56	11.2	10.5	112
20% - 40%	6%	2.95	1.95	2.16	11.3	16.3	48
40% - 60%	46%	3.01	2.38	2.38	12.3	15.7	41
60% - 80%	77%	3.03	2.49	2.74	12.4	16.9	57
80% - 100%	98%	3.39	3.01	3.09	13.8	20.1	160
Average	54%	3.10	2.36	2.45	12.5	16.2	418

Table 11 reduces the graduation rates from Table 12 into three naturally occurring categories. This table is useful for recommending thresholds of achievement of high effect variables, particularly at the completion of the BP in engineering. In order of highest-effect variables, a CC transfer student should strive to achieve a 3.04 or above University first-year GPA, and transfer at least 19.3 credits toward BP courses. For this group of students, this resulted in a 94% or better probability of graduating in engineering, which is a significant improvement over the average graduation rate of 54%. The table also shows how the model may be under-predicting the graduation rates at higher levels.

Table 11. Overall model comparison of graduation probabilities by highest-effect parameters in 30% increments

Predicted Probability of Earned Engineering Degree, Overall Model	Actual Rate of Earned Engineering Degree	CC BP Transfer GPA	University First Fall GPA	University First Year GPA	University First Fall Credit Hours Completed	Number of BP Transfer Credits	N
10% - 40%	3%	2.86	1.66	1.74	11.2	12.2	160
40% - 70%	53%	2.95	2.34	2.42	12.5	16.6	58
70% - 100%	94%	3.33	2.93	3.04	13.5	19.3	200
Average	54%	3.10	2.36	2.45	12.5	16.2	418

Table 12 shows the variance inflation factor (VIF) values for all of the variables in the overall model. Based on the VIFs the variables have low or no collinearity (redundancy).

Table 12. Variance inflation factor values for overall model

Variable	VIF
First Fall GPA	3.47
First year GPA	3.47
Number of BP transfer credits	2.6
University Calculus II credit	2.43
University Calculus I credit	2.25
University Physics I credit	2.18
First year credits completed	1.89
First Spring credits completed	1.56
CC BP Transfer GPA	1.52
First Fall credits completed	1.48
University Chemistry I credit	1.23
Admit year	1.09
Female	1.07
Number of learning communities	1.07

Note: A value less than 5 indicates low or no collinearity

Model Fit Statistics

The model fit statistics for each of the three models are listed in Table 13. These show an increasing ability to predict graduation in engineering as a CC transfer student progresses toward completion of the BP. In the table the test r-square is the amount of variation in the graduation rates that is explained by the variables used to test each model. This is also known as the coefficient of determination. For the one semester and one-year models, about 18% to 20% of the variation in graduation rates is explained by variation of the parameters in the model. In the overall model 35.4% of the variation in the graduation rate is explained by variation of the parameters in the model. This is a significant portion of explained variation.

The train r-square is the amount of variation in the graduation rate that is explained by the variables used to create (train) the model. This is expected to be much higher than the test rates, since 80% of the observations are used to create the model.

The RMSE shows the amount of variation in the chi-square statistic that is accounted for in the model. The RMSE is the extent to which the estimated model differs from the actual model on the average. These decreasing differences between the actual and the predicted values show how the models are progressively better able to fit the data.

Table 13. Model fit statistics

Model	Variability			
	Test r-square	Train r-square	MSE	RMSE
One Semester Model	0.184	0.829	0.109	0.330
One Year Model	0.198	0.863	0.096	0.310
Overall Model	0.354	0.901	0.080	0.282

Supplemental Course Grade Information

The final analysis leads to determining GPA levels for the mathematics and science courses in the BP. These are the courses that traditionally are the most difficult for students (Budny et al., 1998; Levin & Wyckoff, 1990). Table 14 summarizes the GPA levels for the mathematics and science courses in the BP at higher graduation rate levels. Although the course variables do not individually reflect the highest-effect variables, they do constitute part of the overall GPA, which is a high-effect variable in predicting graduation in engineering for CC transfer students. Since these courses may be taken at either the transfer institution or at the University the table lists both institutions. This information may prove supplemental in providing levels of achievement recommended for these key BP courses by institution.

Table 14. Model comparisons of graduation rates by course grades in Calculus I, Calculus II, Physics I, and Chemistry I

Boosted Predicted Probability of Graduation	Actual Rate of Earned ENGR Degree	Calculus I		Calculus II		Physics		Chemistry I	
		University* GPA	Transfer GPA	University* GPA	Transfer GPA	University* GPA	Transfer GPA	University* GPA	Transfer GPA
60%-80%	71%	3.13	2.73	2.69	2.95	2.23	2.61	3.00	2.86
80%-100%	95%	3.26	3.41	3.20	3.34	2.73	3.27	2.50	3.27

*Note: Grades of F were dropped from university GPAs to make them more equivalent to transfer GPAs with no F's transferred

Conclusions and Recommendations

This research discovers high-influence academic variables that a CC transfer student can use to aid in successfully pursuing an engineering degree. Based on the academic and background variables, the two most influential predictors of success are consistently the overall GPA at the university and the number of CC credits transferred that apply to the BP

in engineering. This is in agreement with other studies indicating GPA as the most reliable predictor of retention (LeBold & Ward, 1998; Strenta et al., 1994; Whalen & Shelley, 2010).

This research makes a strong case that even small increases in GPA have significant effects on increasing the graduation rates in engineering. A notable finding is the recommended thresholds of success for the academic variables. In addition, students who transfer more credit toward completing the BP in engineering have higher graduation rates. Based on this research, a conclusive recommendation for students at CCs is to take as many BP courses prior to transfer as possible.

The number of credits transferred toward BP courses could be a measure of both preparation and persistence of the CC transfer student. Since the progression toward an engineering degree begins at Calculus I, students who are calculus-ready are better prepared to study engineering than those who start in remedial mathematics course work. Furthermore, the number of BP credits measures persistence in Calculus, Physics, and Chemistry, all high predictors of success in engineering.

For this group of CC transfers to the College of Engineering, Table 15 summarizes the variables that exerted the highest-influence on graduation in engineering and the recommended thresholds of achievement for these variables. The graduation rate in engineering for students achieving the recommended levels of these high-influence variables was 94%.

Table 15. Summary of influence variables and recommended thresholds

Influence variable	% Influence on earned engineering degree	Recommended Threshold
First-year University GPA	39.5%	3.04
CC BP transfer credit hours	22.0%	19.3
First Fall credits completed	7.2%	13.5
First Fall GPA	6.0%	2.93
CC BP transfer GPA	5.4%	3.33

Table 16 summarizes the recommended thresholds of achievement in mathematics and science BP courses by institution. Although grades are highly subjective, these courses are high predictors of success in engineering. The graduation rate in engineering for students achieving the recommended levels for these courses was 95%.

Table 16. Summary of recommended thresholds for mathematics and science BP courses

Graduation rate in engineering	Calculus I		Calculus II		Physics I		Chemistry I	
	University grade	CC grade	University grade	CC grade	University grade	CC grade	University grade	CC grade
95%	3.26	3.41	3.20	3.34	2.73	3.27	2.5	3.27

Model fit statistics are always important in determining the success of predictive models. Fitting models that predict graduation in engineering is so complex that it is unrealistic to expect any model to explain all or even most of the variation. The most easily understood model fit statistic is the test pseudo-r-square value, which measures the amount of variation in the graduation rates that is explained by the variables in the model. The first fall and first-year models explain about 19% of the variation in graduation rates. The overall model explains about 35% of the variation in graduation rates in engineering, with a parsimonious number of academic variables. This is a very high rate for a predictive model

(Zhang et al., 2004). However, the overall model is measured at the point where a student has completed the BP courses, and most of the attrition in engineering may have already occurred by that point. On average, the models tend to over-predict graduation rates at lower levels, and under-predict graduation rates at higher levels. Other problems with the model fit can be explained by:

1. Missing variables. Social and financial constructs are missing from the models.
2. Measurement error of the variables included in the model
3. Specification error of the variables. Although nonlinearities of exogenous variables need not be explicitly explained in boosted logistic regression models, interactions between variables, and transformations of the endogenous variable are not examined in this work.

In addition, the explained variation in the models do not imply causality. Instead the models can only imply correlations between the exogenous variables and the response variable. Even so, other research studies support the ability of the academic variables to predict graduation rates in engineering (Budny et al., 1998; Levin & Wyckoff, 1990; Tyson, 2011).

Although this study does not consider graduation in a major other than engineering, many of the students who leave engineering do graduate successfully from the university, which makes for a logical extension of this research. In addition, this study does not have the power of a meta-analysis, which would validate and extend the research findings. To test these findings further, the models could be tested against other cohorts of CC transfer students who have had time to complete a degree in engineering. Future research could use this information to develop a classification system to predict success in engineering.

Qualitative research that examines how to raise levels of academic variables also would be helpful.

The study provides a unique perspective and analysis method that will add to the body of research that includes CC transfer student data from the University point of view (Handel, 2010). In addition to increased predictive accuracy, the results of boosted regression are intuitively easier to understand. The emphasis of each model is to develop a useful strategy for advising students, which will increase success rates in engineering. The GPA recommendations are also practical guidelines that would apply for a non-transfer student in engineering.

A problem still exists for students needing mathematics remediation courses. Since the program of study in engineering begins at the Calculus I level in mathematics, the need for remedial mathematics courses delays completion of the BP. In this case, the student will have to take many credits that do not apply to an engineering degree. This is a very specific problem to studying engineering.

To the degree that academic strategies are able to predict success in engineering the levels of achievement in key academic variables are useful. They can be used to design the best program of study and utilize programs for skills improvement, especially in mathematics and science, as needed. This will help illuminate a successful pathway to an engineering degree for a CC student. This may increase the number and diversity of engineers in the workforce.

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CHAPTER 5. GENERAL CONCLUSIONS

General Background

In a global marketplace that is characterized by dependence on knowledge in science and technology, the percentage of Americans who receive degrees in science, technology, engineering, and mathematics (STEM) is estimated at less than 16% of the total bachelor's degrees awarded. At the same time, demand for STEM workers is growing faster than the supply (Increasing the Number of STEM Graduates, 2010).

In 2005, the National Academy of Engineering, National Academy of Sciences, and Institute of Medicine (The National Academies Press, 2007) published *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, which issued a strong warning that America's technological advantages were eroding. In 2010, the same groups published, *Rising Above the Gathering Storm, Revisited Rapidly Approaching Category 5* (The National Academies Press, 2010), to indicate that the storm was increasing in intensity.

The challenge to providing enough STEM graduates has been summarized in the Meeting the STEM Workforce Challenge (2011) as:

1. Failure to attract undergraduate students to STEM studies: "Fewer than one in three college-bound high school seniors is interested in STEM; and about one in six is both interested in STEM and proficient in mathematics, the critical gatekeeper to STEM courses, majors, and careers" (Meeting the STEM Workforce Challenge, 2011, p. 1). Low levels of interest in STEM and proficiency in mathematics reflect a long-term challenge that appears

stubbornly resistant to improvement (Meeting the STEM Workforce Challenge, 2011).

2. Failure to retain those who enroll in STEM majors: More than half of all students enrolling in STEM disciplines move to non-STEM majors before graduation, 35% in the first-year of study (Daempfle, 2003). The exodus among women and underrepresented minorities is especially high (National Center for Education Statistics, 2009).
3. The diversion of those with STEM degrees to other high-paying jobs: Nearly half of all STEM degree holders choose to enter non-STEM fields. In engineering, more than half of engineers enter non-STEM jobs (Meeting the STEM Workforce Challenge, 2011).

Since the 2005 publication of *Enhancing Community College Pathways to Engineering Careers*, from the National Academy of Engineering and the Engineering Research Council (National Research Council, 2005), the educational pathway from the community college to an engineering degree has received considerable attention. However, this same book and others (Handel, 2007; National Research Council, 2005) have documented the difficult realities of successfully pursuing this pathway.

In the past three years, more than 1.4 million additional American students turned to community colleges. That brought the fall 2011 total enrollments to 8.2 million (Baime, 2011). It is estimated that community colleges now educate about 44% of all undergraduates in the United States at one time or another during their college career (American Association of Community Colleges, (AACC), 2011). This number is expected to grow. Between 2007

and 2009 the number of full-time students enrolled in community colleges grew 24% (Mullin, 2011).

Community colleges are a cost-effective means of advancing career skills, obtaining an associate's degree, or working toward a bachelor's degree. Community colleges also provide a more diverse background of students. Of the eight million community college students currently enrolled in for-credit courses, 42% are the first in their family to attend college, 46% are receiving financial aid, and 45% are from an underrepresented ethnic minority group (AACC, 2011). Moreover, students from underserved groups, especially Hispanic and Native Americans, have traditionally enrolled in community colleges in greater numbers than in public four-year institutions. These relative proportions are likely to increase as the population of students from underrepresented ethnic groups is expected to increase substantially in the coming decades (AACC, 2011).

In supporting the progress of students toward community colleges, “not enough data are available on community college student educational pathways. Institutions report that they do not have the funds to collect and analyze data on students.” (National Research Council, 2005, p. 67). “Most often, community colleges lose sight of students once they transfer to four-year institutions, precisely when they should begin tracking their educational and career trajectories. Compiling and publicizing data on transfer students’ success in obtaining B.S. or advanced engineering degrees would demonstrate the effectiveness of engineering studies in community colleges and improve their recruitment rates” (National Research Council, 2005, Executive Summary, p. 5).

Despite all this, there has been surprisingly little rigorous research on institutional effectiveness in community colleges (Bailey, Jenkins, & Leinbach, 2005). Also very little

data are available about community college transfers from the university perspective (Handel, 2007). As community colleges increasingly rely on data to inform institutional decisions about best practices, longitudinal data are needed to assess students' progress through educational institutions. However, assessing student-level data is dependent on data structures, policies, and practices that are difficult to coordinate between community colleges and universities (Mullin, 2011).

Objectives

The goal of this dissertation was to collect and analyze data to determine success strategies for community college transfers to engineering. It does so by analyzing transcript level data collected longitudinally over a 10-year period as community college transfer students' progress before and after transfer into an engineering program. Characteristics of successful students are identified in terms of the academic and social integration variables using descriptive and inferential statistics. In addition to providing data analysis, the results determine distinctive strategies to increase the success of CC transfers in engineering.

The research was funded by the National Science Foundation (NSF) Science Technology Engineering and Mathematics (STEM) Talent Expansion Program initiative. Recognizing the importance of increasing the number of graduates in STEM fields, the NSF has funded the STEM Talent Expansion Program (STEP). One initiative of the STEP program is the Student Enrollment and Engagement through Connections (SEEC) project. SEEC is a collaborative, connection-based alliance between a large Midwestern state university (SU) and an in-state community college (CC) to increase the success of all community college transfers to engineering. This research also takes advantage of the

articulation agreement between all in-state community colleges and the SU to track retention and graduation rates of students based on variables measured at both institutions.

The SEEC project conceptual framework in Figure 1 (Laanan, Rover, Bruning, Mickelson, Shelley, Laugerman, Darrow, & Pontius, 2011) illustrates the progression of CC students toward a degree in engineering and the SEEC intervention strategies. This model shows the many variables affecting the engineering transfer student. The model also includes contributing components of success in engineering that the SEEC project hopes to improve through connections.

This dissertation relies on Tinto's (1993) interactionist theory of social and academic integration as major influences on retention. The Community College SEEC Effects and the University Learning Communities from Figure 1 represent the social integration variables measured to determine if each is successful in increasing retention and/or graduation in engineering for participants. The SEEC Effects from Figure 1 are promising new practices implemented as a result of the NSF SEEC study. They include an integrated program of learning communities, engineering orientation (Engineering 100) offered at the CC, an engineering admissions partnership program (E-APP) between the CC and the SU, and learning communities specifically for transfer students offered at the SU.

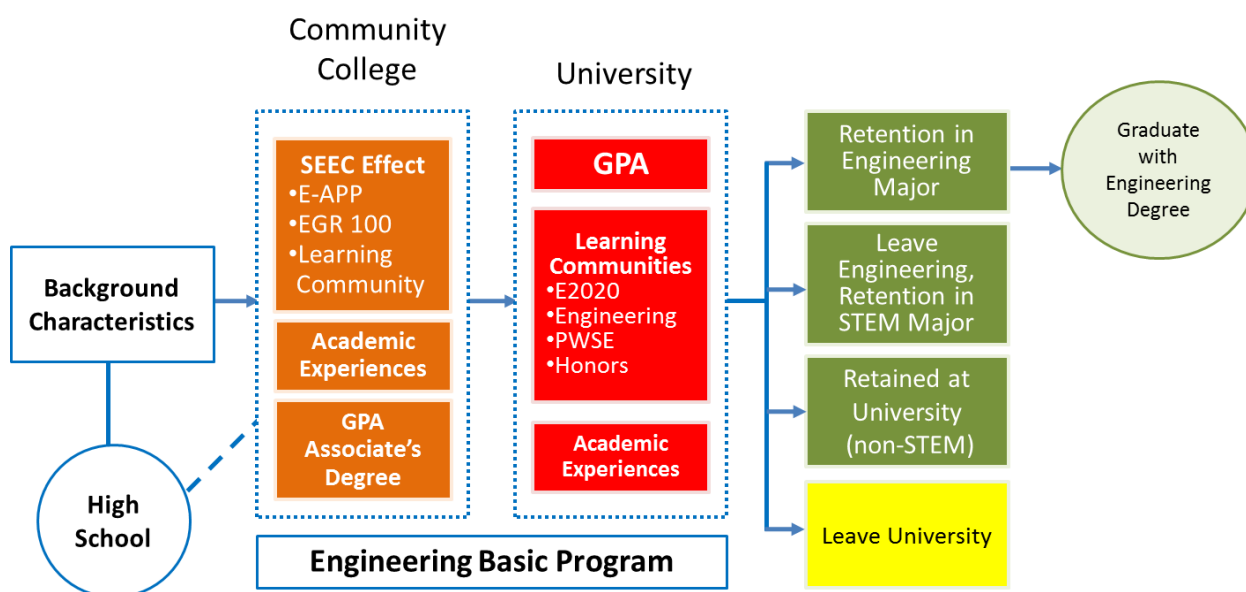


Figure 1. SEEC process model

The Academic Experiences and GPA at the CC and the University from Figure 1 are considered academic integration variables, which are measured for the Engineering Basic Program (BP) courses. These include GPAs in Basic Program Courses, the number of credits taken toward the Engineering Basic Program, and the Academic Experiences including total credits and overall GPAs.

The conceptual process model of the progression toward a degree for a CC transfer student is shown in Figure 2. This shows the CC transfer outcomes as well as the University outcomes possible for a CC transfer student. The effects of success in both transfer outcomes and University outcomes using the BP in engineering are analyzed. Based on these outcomes, levels of achievement in BP courses taken at the CC and at the SU are recommended, which in turn maximizes retention and graduation rates for this group of CC transfer students.

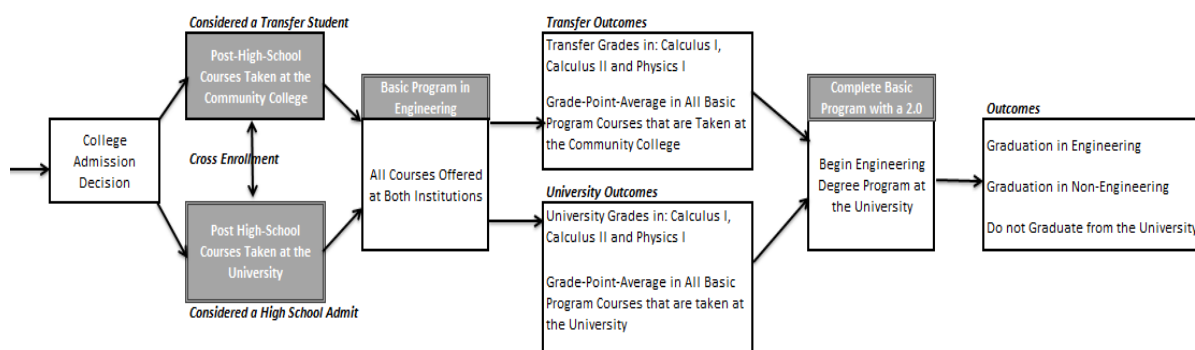


Figure 2. Conceptual process model

Key Findings

The key findings of this research, which can be utilized by CC transfer students as well as non-transfer students, are:

1. Participants in the Engineering Admissions Partnership Program (E-APP) have significantly increased first-year retention rates over non-participants.
2. Since the implementation of SEEC programs, the overall first-year retention rates for CC transfers have increased significantly.
3. Students achieving a Calculus I grade of 3.0 (B) or better at the CC or the SU have significantly improved retention rates.
4. Students achieving a Calculus II grade of 3.0 (B) or better at the CC or the SU have significantly improved retention rates.
5. Students achieving a Physics I grade of 2.0 (C) or better at the SU have significantly improved retention rates.
6. Students achieving an overall GPA in BP courses above 3.0 (B) at the SU have significantly improved graduation rates.
7. Students achieving an overall GPA in BP courses above 3.5 (B+/A-) at the CC have significantly improved graduation rates.
8. Students transferring the sequence of courses Calculus I, Calculus II, and Physics I, or Calculus I and Calculus II, have significantly improved graduation rates.
9. Students who achieve the same GPAs in BP courses (above 2.5) taken at the SU as those of high school admits to the SU have graduation rates equal to those of high school admits.

10. The two most influential predictors of success in engineering for a CC transfer student are SU first-year GPA and the number of CC BP credits transferred. With both of these, even small increases can lead to significant increases in graduation rates.

This study finds that for this group of CC transfer students to have the best chances of graduating with an engineering degree, they need to adopt the social integration strategies offered at the CC, join a learning community at the SU, and focus on being successful in the BP courses, either at the CC or at the SU. It is advantageous in terms of success rates to take Calculus I, Calculus II, and Physics I, or Calculus I and Calculus II at the CC before transfer. Particular focus should be placed on having success in Calculus I and Calculus II with GPA of at least 3.0. Overall, CC transfers can graduate at the same rate as those entering the SU directly from high school if they have similar university BP GPAs.

This research has discovered highly influential academic variables that CC transfer students can use to their advantage in successfully pursuing an engineering degree. These results make a strong case that even small increases in GPA have significant effects on increasing graduation rates in engineering. In addition, students who transfer more credits toward completing the BP in engineering have higher graduation rates. Therefore, a conclusive recommendation for this group of students is to take as many BP courses prior to transfer as possible. The summary of the highest-influence variables and recommended levels are shown in Table 1.

Table 1 Summary of influence variables and recommended thresholds

Influence variable	% Influence on earned engineering degree	Recommended Threshold
First-year University GPA	39.5%	3.04
CC BP transfer credit hours	22.0%	19.3
First Fall credits completed	7.2%	13.5
First Fall GPA	6.0%	2.93
CC BP transfer GPA	5.4%	3.33

To the extent that academic strategies are able to predict success in engineering, the levels of achievement in key academic variables are useful. They can be used to design the best program of study and utilize programs for skills improvement, especially in mathematics, as needed. This will help identify a successful pathway to an engineering degree for a community college student. These programs also have the potential to increase the number and diversity of engineers in the workforce.

These results are of interest to anyone associated with community college students who wish to succeed in the pursuit of a professional engineering degree. The research is significant because of the lack of engineering graduates, and the increasing number of students turning to community colleges to begin their engineering studies. It is also important because of the potential diversity of students that community colleges provide, offering the prospect of adding diversity to the field of engineering. Currently, students at the CCs in this study have lower mathematics aptitude levels (as measured by ACT/SAT mathematics scores and SU grades in Calculus courses) than students who enter the engineering program directly from high school. This could change as the enrollment in community colleges continues to

grow. This study is the first of its kind to track success rates of engineering students by CC performance at this SU.

The research adds to the empirical, descriptive, and quantitative analysis methods that measure and predict success in engineering for community college transfer students. It also adds to the body of community college research that examines success rates of students once they transfer to a university. This study diverges from previous research in that social and academic integration variables are measured both at the CC and at the SU. The results are intended to provide many useful academic and social integration strategies for the CC transfer student and student services professionals who work with CC transfer students based on historical data. Some of these strategies will be applicable to non-transfer students as well.

Sustainability, Recommendations, and Future Directions

Data analysis needs to be ongoing to adjust and manage programs for long-term success. Success rates can be monitored continuously by measuring the following indicators:

- Success in BP courses at both the CC and the SU as measured by grades earned
- Enrollment in Engineering 100 (EGR 100), Learning Communities (LCs), and the Engineering Admissions Partnership Program (E-APP)
- Number and percentage of women and minorities for each indicator
- Matriculation rates of CC transfers who participate in EGR 100, LCs, and the E-APP
- Participation rates in LCs at the SU
- Retention and graduation rates of CC transfers in engineering
- Retention and graduation rates of CC transfers at the SU

Future Direction

Many of the students who leave engineering do graduate from the SU. A logical extension of this research includes measuring academic and social integration variables that predict success for other STEM majors. Ideally, a study that follows students who leave the SU and go on to graduate from other institutions would add to these findings. In addition, this study does not have the power of a meta-analysis, which would validate and extend the research. To investigate these findings further, the models could be tested against other cohorts of CC transfer students who have had time to complete a degree in engineering. Qualitative research that examines how to raise levels of academic variables also would be helpful.

Since much of this work was empirical and descriptive, future work focusing on theoretical and predictive analysis would be beneficial. The information could be used to develop a classification system based on academic and social integration variables from the community college and the university to predict success in engineering. Another extension of this research could include structural equation modeling of academic and social integration variables as predictors of retention and graduation. To do so, a more targeted data collection between the CC and the SU is necessary. Ways to improve the data collected include:

- Identify pre-engineering students early at the CC to target and measure intervention strategies
- Obtain more background information about pre-engineering transfer students
- Include focus group data and interviews of pre- and post-transfer students to engineering

- Follow the students longitudinally after graduation to determine job placement characteristics of CC graduates in engineering
- Identify transfer institution by most credits earned toward the BP. In this study, the most recent institution attended was considered the transfer institution

Combining the social and academic integration variables in this dissertation with other qualitative research studies will further the results and refine the recommendations for CC transfer students. The outcome has the potential to result in increased success in engineering for CC transfer students as well as non-transfer students by targeting and refining the variables that have been shown to have the most influence on their success.

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