Multiple starting lines: Pre-college characteristics of community college and four-year institution engineering students

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Abstract

In response to the pressing need to expand and diversify the engineering workforce, there has been a focus on using community colleges as pathways to four-year engineering programs. To date, there has been little empirical research on the effectiveness of transfer via this pathway for engineering specifically. This analysis compares the pre-college characteristics for students who identify as "pre-engineering" in community colleges with students who initially enrolled in or successfully transferred to a four-year undergraduate degree in engineering. It draws on data from a nationally representative study of 31 four-year engineering institutions and the 15 community colleges which produce the largest number of pre-engineering students in the United States. Specifically, this analysis focuses on the following pre-college characteristic categories: 1) sociodemographic characteristics; 2) high school academic preparation and achievement; and 3) personal and social experiences with which they arrive to college. Findings demonstrate considerable differences between the entering characteristics of community college pre-engineering students, successful transfers, and students first-enrolling in four-year engineering programs for all three categories. Based on these empirical results, we offer recommendations for programs to implement to work toward improving the community college-to-four-year engineering program transfer pipeline.

Introduction

The Obama administration[1] has emphasized that investing in education is a key strategy for maintaining a competitive edge globally, as the U.S. has fallen from first in 1999[2] to ninth in 2010 in college graduation rates[3]. In his 2011 State of the Union Address, President Obama directly spoke to the need to enhance science, technology, engineering, and math (STEM) education. He proposed that STEM education initiatives promote innovation, creativity, and ingenuity in efforts to improve educational success and economic development[4]. Several innovation metrics, such as STEM degree production, change in research and development investment, and access to venture capital indicate that the United States has lost its competitive edge in innovation-based global rankings[5]. As a result, the strategy pitched by the administration joins a series of policy documents demanding increased federal investment in STEM. These reports stress the need for greater emphasis throughout the educational pipeline on producing graduates who can enter and advance a more innovative STEM workforce[6,7,8]. In accordance, the Obama administration has identified community colleges as a potential venue for expanding the pathways into STEM fields and has leveraged and focused resources on the community college sector.

This strategy establishes community colleges as pivotal building blocks for improving the United States' position as the global leader in innovation by the year 2020[9]. To achieve this goal, all citizens are encouraged to participate in at least one year of postsecondary education. Because newly created jobs will require a variety of skills, community colleges will become increasingly important in providing training to citizens who will fill these jobs. Investing in the community college sector could better utilize untapped human resources while allowing broader participation in postsecondary education by those who desire enhanced job opportunities but who may be unable to attend a four-year institution. In addition to this important goal, the administration has identified STEM programs at community colleges as an important first step for students to transfer into four-year degree programs.

Because these new policy initiatives are still being implemented, it is too early to empirically measure their effectiveness. National reports, however, demonstrate substantial differences in the characteristics of students who begin their postsecondary educations in a community college and those who begin their studies in four-year institutions. Some of these differences are demographic; for instance, students entering community colleges tend to be older than those entering four-year colleges and are more likely than four-year students to be female, Black or Hispanic, and low-income[10]. Educational differences, however, are also evident. High school seniors who score low on standardized math tests and complete less advanced math coursework are more likely to enroll in community colleges than seniors who score highly on standardized math tests and take coursework more advanced than algebra II[10].

Although practitioners and researchers have considerable knowledge and understanding of the experiences and achievements of community college students generally[11,12,13], there has been little research on community colleges as a pathway specifically to the bachelor's degree in engineering. Our analyses consider the academic preparations and personal experiences that characterize students who begin the path to an engineering degree in a community college and who plan to transfer to a four-year engineering program. We compare these students with two other groups: 1) community college students who successfully transferred to an engineering program in a four-year college or university; and 2) students who began college at a four-year institution. By comparing students enrolled in the community college to those who have successfully transferred to or started in four-year bachelor's programs, we may better understand the entering pre-college characteristics of community college students that are likely associated with successful transfer to four-year engineering programs.

Literature Review

Many students choose to start their postsecondary educations at community colleges and then transfer to engineering programs at four-year institutions. Mattis and Sislin[14] write, "The community college transfer function is critical to meeting the national need for a robust, diverse engineering workforce. In fact, community college transfer may be the primary mechanism for increasing the number of students pursuing engineering degrees" (p. 11). One study found that one in five students who completed a bachelor's degree in engineering or architecture started his or her college education in the community college sector[15]. The study also noted that the role of the community college "in the engineering path is insufficiently recognized in the literature" (p. 25). This may be because of a lack of awareness of the relatively high proportion of students who transfer from community colleges to complete a bachelor's degree in engineering. Data from a companion faculty survey from our study suggests that engineering faculty are unsure about how many community college students are enrolled in their programs. Many may assume that engineering students on their campuses began their educations at four-year institutions, not recognizing that a significant number of students in their undergraduate classrooms have transferred from a community college.

Students begin their postsecondary educations at community colleges for a variety of reasons, such as proximity to home, lower cost of attendance than four-year institutions, and flexible course schedules allowing students to work full- or part-time while attending classes[14]. Once at the community college, however, many pre-engineering students face obstacles to successful transfer. For example, articulation agreements between community college and four-year institutions are sometimes out-of-date or non-binding[14,16]. Also, students' own academic preparations in mathematics, as well as available courses at community colleges, may not allow them to reach the level of mathematical proficiency needed to be admitted or successfully complete an engineering program at a four-year institution[17].

The connection between college students' entering personal and academic characteristics and a number of student learning outcomes is well documented[18,19]. These characteristics include aspects of students' social identities, such as race and gender, as well as academic preparation factors, including SAT or ACT scores and high school GPAs. An abundance of research on college student achievement points to differences in academic pathways and successes related to demographic characteristics such as race, gender, and income. For instance, women and underrepresented minority students are less likely to pursue science or engineering majors[21,22,23], and low-income students, on average, score lower on standardized tests needed for college admission[24]. Further, low-income students more often need to work for pay because they are more likely than their wealthier peers to have financial obligations to their families[25]. Another factor associated with college student success is parental education levels, which appear to affect students' likelihoods of majoring in science and engineering[26] as well as their probabilities of earning a bachelor's degree in any field[27].

Academic preparation as reflected in high school GPA, high school class rank, and standardized test scores is also a significant predictor of college academic performance[28,29]. One early study of more than 36,000 college students found that a student's high school records and SAT scores were positively related to academic performance in college[18]. Similarly, data on over 1,000 freshmen engineers at Penn State indicated that high school GPA and grades in calculus and physics were the best predictors of persistence in engineering in the first two years[30]. Topics covered in these courses are generally considered to be the fundamental skills that must be in place prior to solving engineering problems.

Zhang, Anderson, Ohland, and Thorndyke[31] used a database of over 87,000 engineering students from nine universities over a 15-year period to relate pre-college demographic and academic characteristics to graduation. Across the nine universities, higher high school GPAs increased the odds of graduating from college; gender also differentially influenced the odds of graduating across institutions. Students' SAT math scores were positively related to graduation, but SAT verbal scores correlated negatively; the authors posit that students with higher verbal scores may switch to other majors where those skills traditionally have been more applicable. Furthermore, students' course-taking patterns and the intensity and quality of their high school curricula are related to their successes in college, as well as the likelihood they will choose and complete a degree in science or engineering[21,27].

In summary, the pre-college student characteristics related to persistence in engineering are generally academic in nature. Certain demographic characteristics are highly correlated to academic achievement, but assumptions of potential success should not be made based on demographics alone. For example, if students from low-income families and impoverished communities complete rigorous math and science curricula, they are as likely to persist as students from more privileged backgrounds[23,32]. Although national statistics provide a profile of community college students *in general*[10,33,34], a specific profile of pre-engineering students enrolled in community colleges is needed. Such a profile could inform the development of services and programs to enhance transfer of pre-engineering students to four-year degree programs and, ultimately, promote the development of a more robust and diverse engineering workforce.

Data and Methods

Data for this analysis are drawn from a broader study funded by the National Science Foundation, entitled BLIND FOR REVIEW. The study collected data from engineering undergraduates and alumni, faculty, program chairs, and associate deans in a nationally representative sample of 31 four-year colleges and universities and from pre-engineering students at 15 community colleges to examine the curricular, instructional, cultural, and organizational features that support learning in engineering programs (Table 1). A team of education and engineering researchers developed the survey-based instruments for each of these populations through a rigorous, two-year process that included: 1) literature reviews; 2) individual interviews with administrators, faculty, and alumni; and 3) focus-group interviews with students. To ensure construct validity (i.e., whether items/response options were comprehendible and appropriate), the instrument was pilot tested prior to sending it to sample institutions.

Data for this paper were collected via three different survey instruments: 1) a survey of pre-engineering students enrolled in community colleges; 2) a survey of currently enrolled engineering seniors and “super-seniors” in their fifth year of undergraduate study; and 3) a survey of engineering graduates surveyed three years after earning their bachelor’s degrees. This analysis focuses on students’ self-reported pre-college characteristics, which tend to have high validity because they are less susceptible to differences in survey question interpretation than other kinds of self-report measures, such as those asking about learning outcomes.

We relied on the American Society for Engineering Education’s database for guidance in drawing this study’s sampling frame, using institution- and program-level information for the 2007–08 academic year for enrolled students. The data sets used in the current analyses were developed using the following sampling and data collection procedures.

Table 1. Institutional Sample

Research Institutions:
Arizona State University (Main & Polytechnic)[1]
Brigham Young University
Case Western Reserve University
Colorado School of Mines
Dartmouth College
Johns Hopkins University
Massachusetts Institute of Technology[1]
Morgan State University[2]
New Jersey Institute of Technology
North Carolina A&T[2]
Purdue University
Stony Brook University
University of Illinois at Urbana-Champaign
University of Michigan[1]
University of New Mexico[3]
University of Texas, El Paso[3]
University of Toledo
Virginia Polytechnic Institute and State University[1]

Master's/Special Institutions:
California Polytechnic State University[3]
California State University, Long Beach
Manhattan College
Mercer University
Rose-Hulman Institute of Technology
University of South Alabama

Baccalaureate Institutions:
Harvey Mudd College[1]
Lafayette College
Milwaukee School of Engineering
Ohio Northern University
Penn State Erie, The Behrend College
West Virginia University Institute of Technology

Community Colleges:
Ann Arundel Community College (MD)
Austin Community College (TX)
Borough of Manhattan Community College (NY)
Brookdale Community College (NJ)
Community College of Baltimore County (MD)
Miami Dade College (FL)
Monroe Community College (NY)
Montgomery College (MD)
Prince George's Community College (MD)
Richland College (TX)
Santa Fe College (FL)
South Texas College (TX)
Union County College (NJ)
Valencia Community College (FL)
Wake Technical Community College (NC)

[1] P360 institution from companion qualitative study which "pre-seeded" the sample
[2] Historically Black College or University
[3] Hispanic-Serving Institution

Four-Year Engineering Student Sample

The sampling for the four-year college students and alumni is disproportionate, mixed random/purposeful, 6 x 3 x 2 stratified using the following strata: 6 engineering disciplines (biomedical/bioengineering, chemical, civil, electrical, industrial, and mechanical); 3 levels of highest degree offered (bachelor's, master's, and doctorate); and two levels of institutional control (public and private). Institutions in the final four-year sample are representative of the population with respect to type, mission, and highest degree offered. This sample purposefully includes five case study institutions that were participants in a companion qualitative NSF study. One of these case study institutions only offers a general engineering degree, so three institutions that offer general engineering degrees were also included in the sample to serve as comparison institutions for a total of seven disciplines. Together, these disciplines accounted for 70% of all baccalaureate engineering degrees awarded in 2008. The Survey Research Center at [name of University omitted for blind review] selected 23 additional institutions at random from the population within the sampling framework. The final sample included 5,406 four-year engineering students and 1,420 engineering alumni.

Community College Sample

The community colleges in the study were chosen using a non-probability purposeful approach. This sample's main purpose was to provide responses from substantial numbers of students in pre-engineering transfer programs. Because such programs are not common, a random sample would not have resulted in a sample with enough numbers of students to provide sufficient cases for analysis. Twenty community college programs that met our criteria of large pre-engineering enrollments were identified through a number of key informants in the community college and engineering education communities, and 15 of these accepted our invitation to participate.

A "pre-engineering" student was defined by the community college; some of these institutions enrolled students in formal pre-engineering curricula, and others identified students seeking transfer to a four-year engineering program. To ensure the quality of the data, a screening question on the community college student survey filtered out students who did not ultimately plan to earn a four-year engineering degree. The first question students encountered on the community college survey asked: How likely is it that you will transfer to a four-year college or university and enroll in a bachelor's degree program in engineering? Survey respondents who answered "probably won't" and "definitely won't" were excluded from the study. The final sample included 1,306 pre-engineering community college students.

Data Collection and Sample Adjustments

A university Survey Research Center was responsible for data collection through a web-based questionnaire. Four-year engineering students responded at a 16% rate, alumni of four-year engineering programs at 19%, and community college students at 15%. Though higher response rates were desired, college student survey response rates around the country have been declining[35,36], perhaps because of increased use of surveys in general through web-based forms[37,38]. We accounted for differences between the sample and the overall population by weighting cases based on response rates by gender, discipline, race/ethnicity, and institutional response rate so that the sample reflected the overall population of engineers. Separate adjustments were made for each surveyed population. In addition, missing data were imputed following procedures recommended by Dempster et al.[39] and Graham[40] using the Expectation-Maximization (EM) algorithm of the Statistical Package for the Social Sciences (SPSS) software (v.18).

Analytic Approach and Methods

We compare pre-college characteristics of three major groupings of students in the community college-to-four-year institution engineering pipeline: 1) community college students enrolled in pre-engineering programs who intend to transfer to a four-year institution; 2) students who successfully transferred from a community college to a four-year institution (where pre-college characteristics are those reported at the time they enrolled in the community college); and 3) students who began their postsecondary engineering educations at a four-year institution, who are referred to as "native" four-year students. Within the four-year institution transfer group, we further identified undergraduates and alumni 1) who had attended community college but not earned associate's degrees; and 2) who had earned an associate's degree from a community college (see Figure 1).

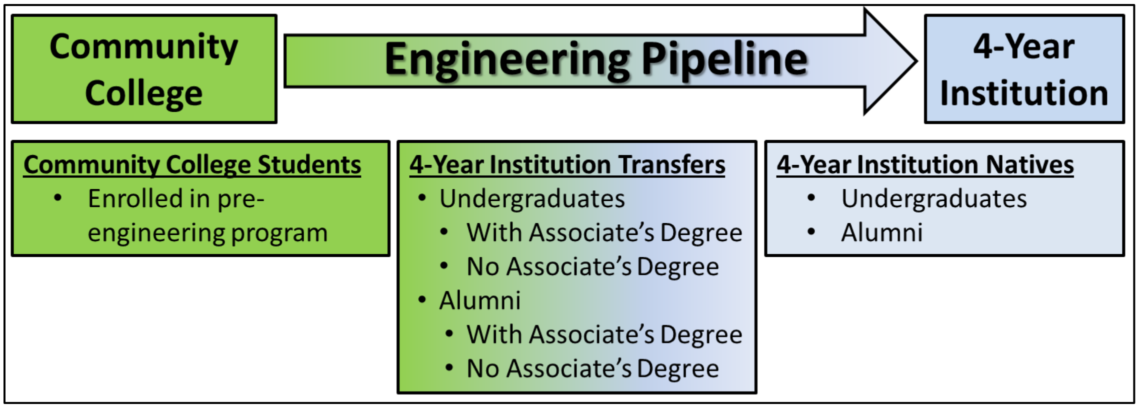

Figure 1. Comparison groups of pre-engineering and engineering students for this study. Pre-college characteristics of four-year institution transfers refer to their self-reported characteristics when entering the community college.

Comparisons of pre-college characteristics between these groups (data permitting) are arranged in three sections: 1) sociodemographic traits, 2) academic preparation and performance, and 3) personal and social experiences. In accordance with Terenzini and Reason's[41,42] college-impacts framework, these sections make up the "pre-college characteristics" component of the model, which hypothesizes that pre-college characteristics both shape students' engagement with various aspects of their institution and also directly affect their learning outcomes. This framework brought coherence to over 50 years of higher education research by conceptually combining a variety of factors that have been empirically shown to shape the "Undergraduate Experience" and to explain student learning outcomes and persistence in college. In this paper we focus on the "pre-college characteristics" component of the framework, where we define "pre-college" as characteristics and experiences that the student "brings with them" to college. In a few cases, however, we also include in our analyses information on students' experiences in pre-engineering community college programs since students then would "bring" these to four-year institutions.

In Table 2 we list the types of "pre-college" variables used in our analyses and note their availability for the three major student groups in this study. Comparisons across groups were done in a variety of ways, depending upon the nature of the data. For each set of comparisons, we present an array of descriptive statistics. Chi-squared analyses were conducted for categorical data to test whether differences in proportions of students across groups are statistically significant. In addition, we completed an analysis of variance (ANOVA) and applied appropriate post-hoc analyses for all pairwise comparisons of continuous variables.

Table 2. List of pre-college variables and data availability (denoted with an X) for each surveyed population.

	Variable	Community College	4 Year Transfer/ Native	Alumni Transfer/ Native
Sociodemographic Traits	Gender	X	X	X
	Race/Ethnicity	X	X	X
	Highest Parent Education Level	X	X	X
	Age when first enrolled in any college	X	X	
	Anticipated age of receiving bachelor's degree	X	X	
Academic Preparation and Performance	SAT Critical Reading	X	X	X
	SAT Writing	X	X	
	SAT Math	X	X	X
	High school grade point average	X	X	X
	First math course taken in college	X	X	
Personal and Social Experiences	Enrollment status (full-time or part-time)	X	X	
	Native English speaker	X	X	
	Hours spent preparing for class	X	X	
	Hours spent working for pay	X	X	
	Hours spent meeting family responsibilities	X	X	
	Hours spent commuting to/from school/work	X	X	
	Reasons for starting at community college	X		

Results and Discussion

Sociodemographic Traits

Chi-squared analyses revealed statistically significant differences across all of the groups (community college pre-engineering students, engineering seniors, and engineering alumni) in gender representation, as well as in the proportion of African Americans, Asian Americans, Hispanic/Latino Americans, and Caucasian/White Americans (Table 3). Women students comprise just over 20% of the native four-year group for both the undergraduate and alumni surveyed populations, consistent with the nationwide female representation in engineering majors[43]. Among community college students in our sample, however, women comprise only 14% of the population. Looking across the transfer groups (four-year and alumni), women on average represent only about 12% of the successful transfer student population. Women who successfully transfer are also less represented among those who earn an associate's degree before making the transfer, as shown by both the undergraduate and alumni populations. Though female engineering students already have a low representation on four-year campuses, their low representation in the community college-to-four-year institution pipeline is even more alarming since this route may be particularly important for talented female students from low-income families.

The opposite patterns are true for African Americans and Hispanic/Latino Americans; these students comprise very low proportions of four-year native students in the undergraduate and alumni populations (approximately 5% and 9%, respectively). Among the community college pre-engineering students, however, African Americans comprise 20% of students, and Hispanic/Latino Americans comprise 28%. Asian Americans have a lower representation in two-year pre-engineering programs. It is noteworthy that Hispanic/Latino Americans maintain this high representation among the transfer student population. Hispanic/Latino Americans' representation among alumni transfers is lower, potentially indicating that the community college pathway into engineering has become more popular in recent years or that four-year completion rates are lower among this group.

In comparison, African Americans are not as well-represented in the undergraduate transfer or alumni transfer populations as they are in the community college population. These students in particular may encounter unique barriers to transfer, either from the start or during their pre-engineering programs. Underrepresented minority students in general are more likely than Caucasian/White and Asian Americans to transfer out of STEM majors prior to degree attainment because, on average, they enter college without the academic preparation required of these disciplines[32]. Our findings raise the question of why there is a difference in transfer representation between African Americans and Hispanic/Latino Americans. Future analyses could examine the interaction of race/ethnicity with experiences in the community college to address this question.

Table 3. Percentages of students populating different groups in the community college-to-four-year engineering pipeline for gender and race/ethnicity.[1] Values in parentheses indicate the weighted number of students falling within a certain category.[2]

Groups	n	Female	African American	Asian American	Hispanic/ Latino American	Caucasian/ White American
CC Student	1306	14% (187)	20% (213)	8% (86)	28% (298)	44% (463)
4-Year: Transfer (No Associate's Degree)	428	15% (64)	12% (46)	11% (40)	29% (108)	49% (185)
4-Year: Transfer (Associate's Degree)	423	11% (45)	3% (11)	21% (78)	32% (116)	44% (163)
Alumni: Transfer (No Associate's Degree)	110	15% (16)	8% (5)	27% (18)	15% (10)	51% (34)
Alumni: Transfer (Associate's Degree)	99	8% (8)	4% (3)	13% (10)	14% (11)	70% (55)
4-Year: Native	4555	21% (948)	5% (175)	16% (584)	11% (374)	68% (2426)
Alumni: Native	1211	22% (270)	6% (57)	17% (163)	7% (69)	70% (660)

[1] Four most common race/ethnicities in the study. Percentages reflect the proportion of a single race/ethnicity in a group, where the numerator is the number of students in the race/ethnicity of interest and the denominator is the sum of the students comprising these four race/ethnicities in a group. Not all students fall within these race/ethnicities.
[2] According to a Chi-Square Analysis, the percentages across all of the groups exhibit statistical differences from the "expected value" for gender and each race/ethnicity category (i.e., "expected" value is the same for each group). Note: sum of percentages in a column may not equal 100 because of rounding.

Representation of Asian Americans and Caucasian/White Americans within engineering is less of a concern. These groups comprise approximately 16% and 69%, respectively, of the undergraduate and alumni four-year native groups and are not underrepresented with respect to the overall population. Though these racial/ethnic groups comprise a lower percentage of the community college pre-engineering student body than their four-year representation (an opposite pattern than African American and Hispanic/Latino students), they appear to be more successful in transferring to a four-year institution based on comparisons of the proportionality of students across groups. Asian Americans have nearly twice the representation among transfer students who first attain an associate's degree (21%) compared to those who do not (11%) for the undergraduate surveyed population, but the opposite is true for the alumni population (13% versus 27%, respectively). With our data we are unable to address why there is a different pattern between the undergraduate and alumni samples for this variable.

Table 4. Percentages of parents' highest education level (mother, father, or guardian) for different groups in the community college-to-four-year engineering pipeline.[1] Values in parentheses indicate the weighted number of students falling within a certain category.

	Highest Parent Education Level							
	<HS	HS	Some College	Technical Certificate	Associate's	Bachelor's	Master's	Doctorate
CC Student	11% (140)	21% (276)	10% (128)	17% (217)	7% (93)	18% (241)	12% (159)	4% (52)
4-Year: Transfer (No Associate's Degree)	9% (37)	9% (37)	8% (35)	2% (8)	14% (61)	31% (133)	18% (77)	10% (42)
4-Year: Transfer (Associate's Degree)	13% (56)	13% (53)	12% (52)	4% (16)	11% (46)	30% (126)	15% (64)	2% (10)
Alumni: Transfer (No Associate's Degree)	2% (2)	26% (29)	13% (14)	3% (3)	4% (4)	43% (48)	6% (7)	4% (4)
Alumni: Transfer (Associate's Degree)	10% (10)	12% (12)	29% (29)	2% (2)	14% (14)	21% (21)	10% (10)	1% (1)
4-Year: Native	2% (98)	6% (256)	6% (254)	3% (124)	11% (513)	29% (1323)	31% (1413)	13% (575)
Alumni: Native	2% (19)	5% (64)	6% (77)	6% (67)	5% (58)	34% (410)	26% (318)	16% (197)

[1] Percentages reflect the proportion of a single education category within a group (i.e., within a row), where the numerator is the number of students in the parent education level of interest and the denominator is the sum of the number of students within a group (i.e., sum of the row).
Note: sum of percentages in a column may not equal 100 because of rounding.

We also compared parents' educational levels across the groups, where the variable reflects the highest educational level reached by a student's mother, father, or guardian (Table 4). This variable may be related to a number of different factors associated with student success in college, including socioeconomic status (family income data were not collected in the study because of concerns about students' abilities to report income accurately), access to resources during elementary and secondary school, or access to social networks of college-educated individuals. Table 4 indicates that community college students' parents tend to have lower educational levels than native four-year students. Only one-third of the community college students' parents earned at least a bachelor's degree relative to three-quarters of the native four-year students' parents (for both the alumni and undergraduate populations). This large discrepancy may represent differential access to resources and information about higher education in general, which can affect students' college choice decisions[44,45,46].

The parental education level of transfer students tends to fall between that of students in the community college and four-year native student groups. This is both an intuitive and troubling finding. Intuitively, families with higher educational levels (i.e., at least a bachelor's degree) may push their children to transfer to a college or university where they can attain a bachelor's degree so that their children follow a similar educational path as their own. In addition, students from families in which at least one parent or guardian attended a four-year institution may have greater access to information (e.g., articulation agreements and opportunities to transfer) than those from families without exposure to college[44]. We argue that this finding is troubling because 77% of the community college sample indicated that they will definitely transfer, and 19% answered that they would probably transfer. The significant differences between the highest parental education level for community college students and that of the families of students who successfully transferred to a four-year program suggests that at least some pre-engineering community college students may be disadvantaged by a lack of information resources. Thus, the community college students (and their institutions) still face a challenge in "closing the gap" for reasons related to differences in parents' educational levels.

Comparisons of age at enrollment and anticipated age of receiving the engineering bachelor's degree also indicate differences across groups (Figure 2). The average age at enrollment for community college students is four years older than the average starting age of engineering students native to 4-year institutions, with the transfer populations falling in the middle. According to an ANOVA ($p<.05$), these differences are significantly different for each pairwise comparison. Successful transfer students who earned an associate's degree tended to start community college at an older age than those who transferred without the degree. Similarly, attaining an associate's degree before transferring was also related to being older at the time of receipt of the bachelor's degree. A separate ANOVA ($p<.05$) indicates that the anticipated age for earning an engineering bachelor's degree significantly differs across all groups.

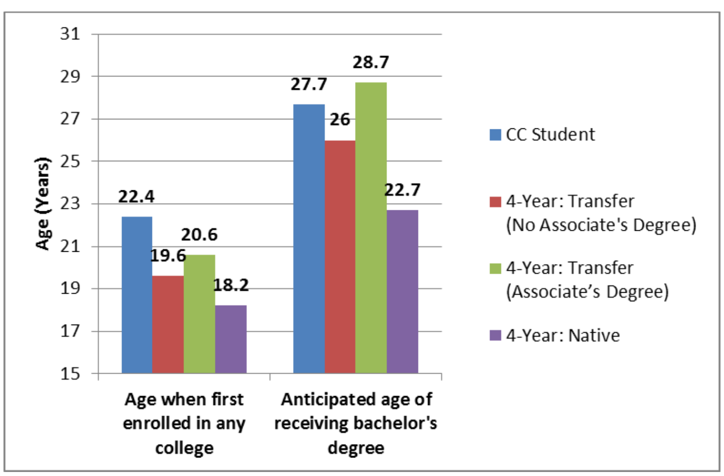

Figure 2. Comparisons across different groups in the community college-to-four-year engineering pipeline for age of initial college enrollment and anticipated age of receiving a bachelor's degree.

Perhaps the most important implication from this comparison is the different expected length of time-to-degree between these groups (calculated as the difference between anticipated age of bachelor's attainment and age of college entry). Students who are four-year natives anticipate 4.5 years on average from enrollment to degree attainment, while community college students expect 5.3 years to graduate. For successful transfers who did not complete an associate's degree, the expected cumulative time to a degree was 6.4 years; associate's degree recipients anticipated 8.1 years. Relative to these latter estimates, our findings suggest that community college students who expect to transfer and receive a bachelor's degree in engineering may be underestimating the amount of time needed to complete their postsecondary educations by an average of one to three years.

Academic Preparation and Performance

Our data exhibit stark differences across groups for variables related to pre-college academic preparation and performance (Table 5). The largest discrepancies between groups were observed for the SAT math scores, a troubling finding given the importance of mathematical skills for admission to and academic success in engineering programs. Students who began their college educations at a four-year institution (for undergraduate and alumni samples) scored 150 points higher than community college students on average[1]. Math SAT scores for transfer students from community colleges and four-year institutions fall in between these groups, with higher scores reported by students who did not earn an associate's degree compared to those who did.

Though much focus is placed on a foundation in mathematics as pre-requisite for engineering (and indeed average SAT scores for each group were highest for this component), there were also significant differences in SAT critical reading and writing scores for the student groups we examined (see Table 5). According to an ANOVA and post-hoc analyses, community college pre-engineering students scored lower on average on the critical reading section of the SAT than all other groups, with the exception of the transfer students who first earned an associate's degree. Students who began their college educations in a four-year institution (for both our undergraduate and alumni samples) scored significantly higher than all other groups. Transfer students who earned an associate's degree prior to transferring to a four-year engineering program scored significantly lower than those transfer students who did not earn an associate's degree (again for both the undergraduate and alumni samples). For the SAT writing test, an

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[1] The community college mean SAT score may be an overestimate of community college students' mathematics preparation. As the SAT is not required for community colleges, 61% of students in our sample did not report a score. Because we imputed all missing data, in accordance with norms to address non-response biases[47], each student in our data set was assigned an SAT score based on responses to other questions. Students reporting SAT scores would be more likely to have considered a four-year institution simply because they took the test. One could assume that SAT takers would have performed better than students who had no intention of taking the test, and these higher "actual" scores would factor into the calculation of missing scores. Thus, the disparity in SAT scores between community college students and students enrolled in four-year institutions may be underestimated.

ANOVA and post-hoc analyses also show that each group is significantly different from every other group, with the same ordering of groups as for the SAT critical reading scores.
Similar patterns in academic preparedness across groups emerge for the high school grade point average variable (Table 5). When using high school GPA as a proxy for academic preparation, community college pre-engineering students are the least well-prepared academically, with most students reporting GPAs falling in the range of 3.00–3.49. Students who successfully transferred to four-year engineering programs have the next highest grade point averages, and students who began college in a four-year institution are the most academically prepared. Despite representing different student populations across a period of time that could span eight years, the grade point averages of native undergraduates and alumni are remarkably similar, as 81% of each group earned a 3.5 or above in high school, and 15% ranged from 3.0– 3.5 (note the categorical nature of GPA response categories). Perhaps this consistency is a statement of the types of pre-college characteristics valued by admissions committees in the four-year sector or a self-selection of well-prepared high school students for four-year engineering programs. In addition, as with SAT scores, transfer students who earned an associate's degree were less prepared academically than those who did not earn the associate's degree but still successfully made the transfer.

Table 5. Comparisons across different groups in the community college-to-four-year engineering pipeline for components of the SAT and high school grade point averages. Standard deviations for the SAT are presented in parentheses.

	SAT Scores			High School Grade Point Average					
	Critical Reading	Writing[1]	Math	< 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	> 3.50
CC Student	482 (129)	470 (131)	528 (130)	1%	2%	12%	21%	35%	28%
4-Year: Transfer (No Associate's Degree)	540 (79)	541 (85)	629 (67)	1%	3%	4%	15%	29%	47%
4-Year: Transfer (Associate's Degree)	479 (96)	498 (100)	596 (81)	2%	2%	10%	15%	43%	28%
Alumni: Transfer (No Associate's Degree)	569 (80)		633 (72)	1%	2%	5%	20%	40%	32%
Alumni: Transfer (Associate's Degree)	534 (102)		604 (102)	2%	4%	12%	19%	47%	15%
4-Year: Native	611 (89)	610 (87)	681 (70)	0%	0%	1%	3%	15%	81%
Alumni: Native	612 (88)		687 (71)			0%	4%	15%	81%

[1] The SAT Writing section did not exist when alumni were in high school.
Note: sum of percentages may not equal 100 because of rounding.

Discrepancies in math preparation become even more apparent across groups for comparisons of the first math course students took in college (Figure 3). While 93% of students native to four-year institutions first enrolled in calculus or a more advanced course, only 22% of community college students began their study of mathematics in college at this level. Nearly a fifth of the pre-engineering community college students took a remedial math course below the algebra level as their first college math course. Only 7–8% of students who successfully transferred to a four-year institution from a community college started in such a remedial course; it appears to be possible, although uncommon, for students who are less well-prepared for the advanced mathematics required for engineering majors to "catch up" to their peers who started their college educations at four-year institutions. Consistent with our previous findings, transfer students who did not earn an associate's degree are more similar in terms of their course-taking profile to native students, and transfer students who earned an associate's degree are more similar to students who begin their educations in community colleges.

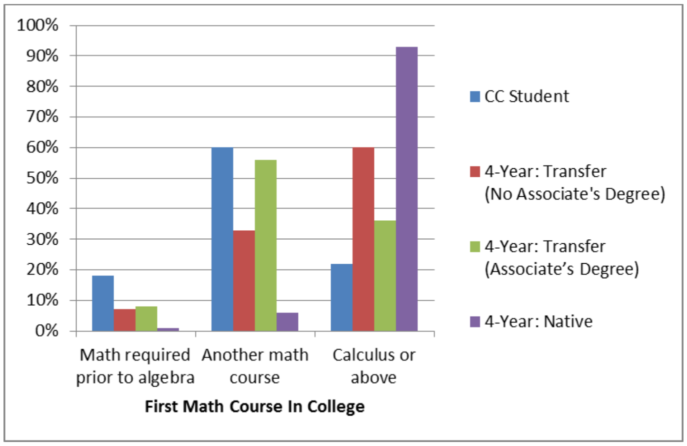

Figure 3. Comparisons across different groups in the community college-to-four-year engineering pipeline for the first math course taken in college.

Personal and Social Experiences

Students in each grouping also enter college with a different set of personal and social experiences that may slow or impede progress in the engineering pipeline. Over a quarter of community college students enroll on a part-time basis, and nearly 40% report that English is their second language (Table 6); in comparison, only 1% of the students who began their college educations in a four-year institution reported enrolling part-time, and 10% reported English as a second language. Though our community college sample of institutions includes several Florida and Texas schools (potentially biasing the native language variable because of these states' relatively high populations of non-native English speakers), these differences are nonetheless noteworthy. Students who first enroll in four-year institutions are more likely to be able to devote full attention to school. Similar to patterns for pre-college academics, transfer students who earned an associate's degree more closely resemble community college pre-engineering students on this language variable, while transfer students without the associate's degree are more similar to students who first enroll at the four-year institution.

Table 6. Comparisons across different groups in the community college-to-four-year engineering pipeline for enrollment status and whether a student is a native English speaker.

	Enrollment Status		**Native English Speaker**	
	Part-Time	**Full-Time**	**No**	**Yes**
CC Student	28%	72%	39%	62%
4-Year: Transfer (No Associate's Degree)	7%	94%	24%	76%
4-Year: Transfer (Associate's Degree)	16%	84%	31%	69%
4-Year: Native	1%	99%	10%	90%

Note: sum of percentages may not equal 100 because of rounding.

Our surveys also asked students to estimate the amount of time they spent each week on various activities and revealed that community college students in particular must balance a variety of activities in addition to school (Figure 4). Not including time spent preparing for class, community college students on average spend a 40-hour week working for pay, meeting family responsibilities, and commuting to and from work. Community college students spend significantly less time preparing for class and more time on non-academic activities than every other student group. These student reports illustrate the kinds of responsibilities that pre-engineering students in community colleges typically juggle in addition to schooling.

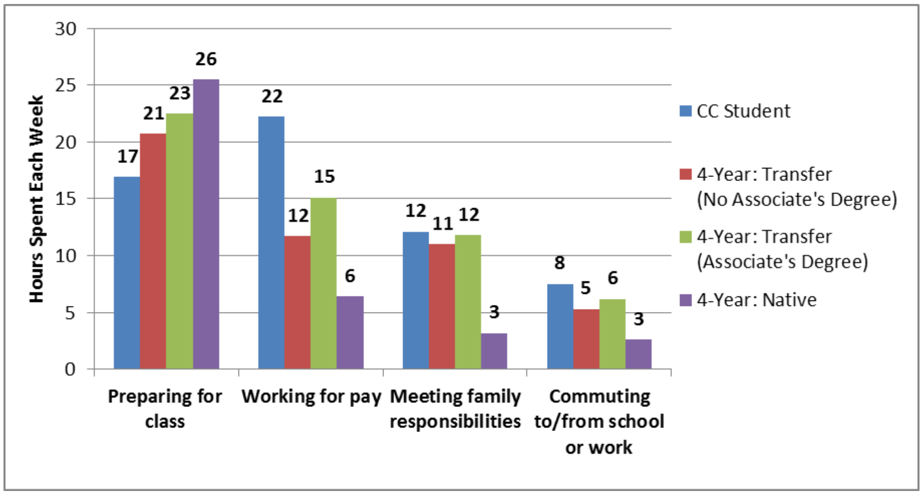

Figure 4. Comparisons across different groups in the community college-to-four-year engineering pipeline for time spent on different activities each week.

Table 7. Average responses on a 5-point Likert scale[1] asking pre-engineering community college students about the importance of various factors in beginning postsecondary education in the community college sector.

Importance of:	**Mean**
Cost	3.70
Transfer agreement with a four-year engineering program	3.33
Flexible course scheduling	3.13
Close to home/family/friends	3.04
I knew I would get in	2.91
Family/work obligations	2.67
Good place to find out if I was ready for college-level courses	2.62
Received financial aid	2.51
Diverse student population	1.97
I applied but wasn't accepted to a four-year school	1.60
English as a Second Language program	1.51
On-campus childcare	1.16

[1] 1: not at all important; 2: slightly important; 3: moderately important; 4: very important; 5: extremely important

Finally, community college students were asked to report on the importance of a set of potential factors that contributed to their decision to enroll first at a community college (Table 7). With this set of questions, we sought to generate a better understanding of which aspects of their pre-college personal and social experiences were priorities in choosing this educational pathway. Among these students, the most important factor was the cost of education (3.7 on a 5.0 scale, where 1=Not at All Important, 5=Extremely Important), which aligns with findings related to socioeconomic status presented in analyses of other variables. The second most important factor was a transfer agreement with a four-year program (average rating of 3.3), indicating that transfer agreements mattered almost as much as cost. A limitation of the study is that there is no comparison group (i.e., successful transfers) for this set of questions. Thus, we do not know whether there are differences in perceptions of important factors affecting the transfer process between the pre-engineering community college students and successful transfer students.

Being close to home/family/friends (mean = 3.0) and flexible course scheduling (mean = 3.1) were also rated as moderately to very important factors in the decision to begin college in a two-year institution. This result aligns with our previous findings on time restrictions caused by activities outside of school. On average, pre-engineering students in the community college were less influenced in their educational choices by the provision of on-campus childcare or programs for non-native English speakers. They also rated financial aid as only slightly to moderately important, although this may be a reflection of the low tuition rates at community colleges rather than a comment on the need for financial aid for further educational pursuits.

Conclusions, Recommendations, and Future Research

In summary, our research demonstrates a number of differences in pre-college characteristics between students beginning their postsecondary educations in community colleges, students who successfully transferred to four-year institutions, and students who began in a four-year engineering program. Though based on cross-sectional data, these findings allow us to consider how pre-college characteristics and experiences may influence the academic pathways of students interested in engineering majors and careers, and provide strong bases for hypotheses about the impact of pre-college factors on the shape of the engineering workforce.

Our findings suggest a unique set of pre-college characteristics are associated with a unique set of barriers to completing a bachelor's degree in engineering and suggest how two- and four-year institutions might tailor support for different populations of students in the community college-to-four-year institution engineering pipeline. For example, our results indicate that women are under-represented in the community college and transfer student samples (approximately 15%) relative to their proportionality in four-year engineering programs (20%). This is consistent with single-institution research on engineering transfer students conducted by Laanan, Jackson, and Rover[48] that showed an over-representation of males among transfer students. For female students in general, it appears as if recruitment is a bigger challenge than retention[49]. Community colleges could use our results to benchmark progress toward a goal for enrolling additional female students. Increasing female representation by 5% to equal the 4-year institution average appears to be a reasonable, empirically driven target that would work toward diversifying the field. In general, retention of historically underrepresented minority students in STEM is a challenge because in the aggregate these students tend to have less rigorous academic training in elementary and secondary school[49]. The community college appears to be a more successful route to the engineering bachelor's degree for Hispanic/Latino students than it is for African American students; the former are better represented in our community college and successful transfer student samples than the latter. Future work should compare experiences in community colleges (and experiences prior to postsecondary education) between these underserved groups to determine whether new insights about intervention or recruitment programs can be uncovered.

Many students use community colleges as a pathway into higher education, but many do not realize their ultimate goal of a four-year degree in a timely fashion. In California, for example, only a quarter of community college students meet this goal within a six-year time frame[50]. Our analyses showed significant differences in the anticipated length of time to reach a four-year engineering degree between community college students and successful transfer students by as much as three years. Both community colleges and four-year institutions thus stand to do a better job disseminating information about curricular sequencing, pre-requisites, and articulation agreements to allow these students to make more attainable educational plans. Since many students taking advantage of this pathway face financial hurdles to completing their educations, it is especially important for these students to be able to plan ahead with respect to tuition payments.

In all likelihood, misunderstandings about mathematics pre-requisites for pre-engineering courses contribute to this inaccuracy. We show that students in the community college sector arrive to pre-engineering programs with significantly less-advanced math preparation than students who transferred to or began at a four-year institution. The advanced mathematics required for entrance into and success in bachelor's degree programs in engineering suggests that inadequate math preparation is one of the most significant stumbling blocks for pre-engineering students in community colleges. Several intervention attempts could work to mitigate this issue. Better communication downstream to teachers in elementary schools and teachers and counselors in secondary schools is a start. In addition, four-year and community college administrators should disseminate transparent policy information and articulation agreements indicating courses needed to transfer to engineering programs at four-year institutions. Careful planning in advance may reduce the number of additional math courses a student may have to take after graduating from high school; this, in turn, would help reduce the time to degree.

Strategic delivery of remedial math courses may also enhance student success in pre-engineering and engineering programs. By focusing remedial math courses on engineering applications, for example, community colleges could sustain or spark students' interests in engineering careers and could also help familiarize them with the types of real-world problems encountered by engineers. Remedial math courses are likely to include students who have not had the math needed for engineering degrees – but who are very capable of high-level mathematics, as well as students with less well-developed math skills. Separate math sections are not necessarily practical or the only solution to this challenge. Peer-instruction strategies could pair high-achieving students with those having more difficulty to support struggling students and further enhance the learning of more advanced students. Research shows that peer collaboration promotes the achievement of both weaker and stronger students, with both groups showing learning gains as a result of their interactions[51]. Another recommendation for how the math gap can be addressed is to offer highly focused pre-semester programs. For example, one Hispanic-serving institution in California offers a two-week summer mathematics program to help students prepare for college-level math courses. The program not only enhances placement test scores, course performance, and STEM retention overall, but it also helps create a sense of community for participants before actual semester courses begin[52].

Creating this sense of engagement on community college campuses is challenging, as our results show that over a quarter enroll in pre-engineering programs on a part-time basis, and the average student in the community college sample has over a 40-hour work week of other responsibilities *before* considering classes. Combined with the time-to-degree finding, these students who take longer on average to complete a bachelor's degree are more likely to have outside commitments out of school and are less likely to have substantial funds to pay for college (relative to 4-year natives). Thus, to support community college students, pre-engineering programs should consider ways to help students balance academic and other responsibilities. As the federal government expands investments in the community college sector, some of these resources could be used strategically to engage students outside of class. For example, community colleges could develop purposeful work-study opportunities for pre-engineering students. For example, hiring peer tutors would keep pre-engineering students on campus and ease scheduling difficulties and potentially replace less meaningful off-campus work. Such a program would also help students who may be struggling in the pre-engineering program. In addition, working with local companies to provide paid internship experiences at engineering firms would keep students in the field and provide important socialization and mentoring opportunities. Addressing these barriers by creating new opportunities to gain engineering knowledge will ultimately support successful transfer to four-year engineering programs.

As we reported our results, we frequently noted that transfer students who did not earn an associate's degree are more similar to native students than those who did earn an associate's. Conversely, transfer students who earned an associate's degree are more similar to community college students than to four-year native students. We offer two potential explanations for this pattern. First, students who are less prepared academically tend to come from less advantaged backgrounds. In these communities, attaining an associate's degree may be more commonly encouraged than in wealthier communities; additionally, the associate's degree is a less expensive and thus more realistic option for earning the bachelor's degree. Second, students who are less prepared academically may use the associate's degree to indicate to four-year institutions that they are capable of success at in four-year programs.

In general, we also consistently found that, in the aggregate, transfer students sit between the community college student sample and four-year native student population in terms of pre-college characteristics. This suggests that only a subset of community college students ultimately successfully transfer to a four-year engineering program. Our results suggest a number of directions for future research. First, researchers should examine interaction effects. Many of the life experiences reported by students in our sample are likely related to their sociodemographic variables. Future analyses should consider the interaction of several sociodemographic variables on students' experiences, outcomes, and transfer. Longitudinal research designs would also address the limitations of our cross-sectional design, tracking individual students through the community college-to-four-year institution pathway to further explore how pre-college experiences influence academic success at various points in the path. Future work could also try to predict transfer success based on pre-college characteristics. Results could help direct resources within pre-engineering programs toward students who are most likely to succeed in engineering and what kinds of assistance they might need. Moreover, if a student is not predicted to transfer successfully, further analyses could look at what exactly differs about those students to identify potential interventions. Researchers should also examine the community college experiences of transfer "outliers" who were able to transfer (and thus outperform expectations based on precollege characteristics). Such findings may reveal particular experiences in pre-engineering community college programs that may have helped outliers succeed in transfer and beyond.

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