Examining the Tracks That Cause Derailment: Institutional Contexts and Engineering Degree Attainments

Bryce E. Hughes, Juan C. Garibay, Sylvia Hurtado, Kevin Eagan
University of California, Los Angeles

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Increasing the number of engineers is a growing national concern as the engineering profession anticipates a wave of retirements in the next few years while the U.S. is confronted by tremendous infrastructural and environmental challenges (PCAST, 2012). Charles Vest warned, in the 2011 National Academy of Engineering report *Lifelong Learning Imperative in Engineering*, "During the next several years there will be massive retirements of skilled and experienced engineers, and the United States has one of the lowest rates of graduation of bachelor level engineers in the world: only 4.5 percent of our university graduates are engineers" (Dutta, Patil, & Porter, 2012, p. ix). Despite its national import, much is still unknown about the factors that positively influence engineering degree completion.

Previous studies have largely pointed to student-level variables to explain the high attrition rates in engineering. Research shows that students' self-efficacy, academic preparation, attitudes toward engineering, experiences with instructors, and interactions with peers all play a role in students' decisions to leave engineering (Besterfield-Sacre, Atman, & Shuman, 1997; Cross, 1993; Veenstra, Dey, & Herrin, 2009; Zhang, Anderson, Ohland, & Thorndyke, 2004). Others have examined the engineering classroom experience, particularly the prevailing mode of instruction, to show how the reliance on lecturing, norm-referenced grading, and individual-based work may influence engineering student attrition (e.g., Astin, 1993; Seymour & Hewitt, 1997). Institutional-level measures, however, have largely been left out of the discussion in past research on the influences of engineering completion.

In line with the engineering profession where great innovations are fostered within the right environment (Johnson, 2010), educational research suggests that so too is the development of engineering talent (ASEE, 2009; 2012). Despite the importance of institutional-level factors in bachelor's degree completion, generally (e.g., Oseguera, 2005), and STEM degree completion, specifically (e.g., Hurtado, Eagan, & Hughes, 2012), institutional factors of interest to educators, practitioners, and policy makers in engineering education remain under-examined within the engineering education literature. While a focus on students' preparation and experiences in STEM courses are important, much is unknown about the institutional factors that may divert engineering talent into other fields. The purpose of this study is to identify contextual factors that contribute to engineering degree completion within five years using hierarchical generalized linear modeling on a national longitudinal dataset of 15,913 students from 270 institutions.

Literature review/Theoretical Framework

In order to better understand the influence of institutional contexts on engineering degree completion, this study is informed by Bronfenbrenner's (1979) theory of human ecology. Bronfenbrenner's theory organizes a person's environment into a series of nested systems in which people interact, namely microsystems, mesosystems, and macrosystems. Conceptualizing the college environment as a nested series of microsystems, mesosystems, and macrosystems, we identified factors of interest within each of these environments to examine how they may affect engineering degree completion. This section reviews literature on engineering, and in some cases, STEM, completion as it pertains to each of these systems. We will first discuss the pre-college characteristics that constitute our control variables.

Previous studies in engineering education have shown that several pre-college experiences and background characteristics are associated with whether students decide to pursue and whether they are retained along the engineering pipeline. Factors predicting with students' interest and pursuit of an engineering degree include early exposure to the field of engineering (Watson, Pierrakos, & Newbold, 2010) and having parents who are in an engineering career (Barnard et al., 2012; Lichtenstein et al., 2009). Research has shown that engineering persistence and retention are related to students’ prior knowledge of engineering (Good, Halpin, & Halpin, 2002), engineering career aspirations (Li, Swaminathan, & Tang, 2009; Shuman et al., 1999), intrinsic motivations to become an engineer (Burtner, 2005), impressions of an engineering career (Besterfield-Sacre, Atman, & Shuman, 1997; 1998), and commitment toward majoring in engineering (Besterfield-Sacre et al., 1997; Shuman et al., 1999). Additionally, pre-college preparation, especially in math and science, and access to quality educational resources are critical for STEM students’ (AAAS, 2001; Chang et al., 2008; Denson, Avery, & Schell, 2010; Ellington, 2006; Kuh et al., 2007; LeBeau et al., 2012) and engineering students’ success (Tyson, 2011; Veenstra, Dey, & Herrin, 2009; Zhang et al., 2004).

Microsystem – The Classroom Environment

The nested system most proximal to students is the classroom environment. Multiple factors within the engineering classroom environment have been cited as contributing to high attrition rates in engineering, including lecture-based pedagogy, norm-referenced grading (i.e., grading on a curve), and individual-based work (Astin, 1993; Seymour & Hewitt, 1997). In addition to teaching practices and curriculum, the engineering classroom climate, which is often described as “unwelcoming,” may also influence attrition (ASEE, 2009; Fitzmorris, Trytten, & Shehab, 2010; Litzler & Young, 2012). Vogt (2008) found that students’ perceived faculty distance has a negative impact on engineering students’ self-efficacy and academic confidence, and an indirect negative effect on their GPA. A “chilly” classroom climate has also been cited as a concern for the success of women and students of color in engineering (Brown, Morning &

Watkins, 2005; May & Chubin, 2003), especially at predominantly white institutions (Newman, 2011).

Mesosystem – Co-Curricular Experiences

Even though co-curricular experiences tend to be just as proximal to individual students as their classroom experiences, we conceptualize these as the mesosystem because they serve as connections between the classroom and the broader engineering community. Engineering departments are implementing a range of co-curricular experiences in hopes to enhance the educational process and improve retention and completion rates, including internships, cooperative experiences, and research opportunities (ASEE, 2012). Internships provide students direct work experience with an engineering firm, and cooperative experiences place students in an engineering work environment for as much as a year or more as part of their course requirements for their degree (Do, Zhao, Trytten, & Wong Lowe, 2006; Jaeger, Eagan, & Wirt, 2008). Undergraduate research experiences provide an inquiry-based learning environment to give students hands-on practical experience with science and engineering (Freeman, 2000; Kinkead, 2003; Zydney, Bennett, Shahid, & Bauer, 2002).

Additionally, many institutions have implemented targeted retention programs for underrepresented racial minority students in engineering and have demonstrated success in improving the retention and persistence rates (ASEE, 2012; Good, Halpin, & Halpin, 2002; Ohland & Zhang, 2002). These programs often provide students a sense of community and academic support within engineering programs (May & Chubin, 2003). Many institutions also provide financial assistance that meets a critical need for underrepresented students in engineering (ASEE, 2012; Georges, 2000), and a great deal of federal and foundation support has been allocated to sustain and enhance these programs across the nation (Bennof, 2004; National Academy of Sciences, 2011).

Macrosystem – Institutional Context and Characteristics

Most distal from the student experience is the institutional macrosystem. Various institutional-level characteristics have been shown to influence degree completion or retention in the STEM fields, including size (Hurtado, Eagan, & Hughes, 2012; Oseguera, 2005), selectivity (Bowen & Bok, 1998; Bowen, Chingos, & McPherrson, 2009; Espinosa, 2011), whether the institution is private or public (Espinosa, 2011; Ishitani, 2006; Titus, 2006), and minority-serving institutions (Crisp, Nora, & Taggart, 2009). Institutional type, such as research universities or liberal arts colleges, has also been shown to have an impact on degree completion (Astin & Oseguera, 2005), although this effect may be moderated by race/ethnicity (Oseguera, 2005).

Finally, in addition to the structural characteristics of institutions, the peer normative context has also been found to have an effect on degree completion and persistence (Berger & Milem, 2000; Oseguera & Rhee, 2009; Titus, 2004). The peer normative context refers to aggregated attitudes and characteristics of an institution’s student body. In particular, the proportion of premedical majors at a given institution has been found to have a negative impact on STEM retention and degree completion (Chang et al., 2010; Hurtado, Eagan, & Hughes, 2012), which may be attributed to a higher level of competitiveness on campuses with higher numbers of premedical students (Gasiewski et al., 2012).

Method

Data

Drawing from a national sample of students and institutions, this study examines the individual- and institutional-level factors that jointly predict students’ likelihood of completing a bachelor’s degree in engineering relative to completing a bachelor’s degree in a non-engineering field or not completing a degree within five years of entering college. We focus on five-year completion as many engineering programs offer five-year combined bachelor’s and master’s degree programs and often provide a curriculum that typically takes longer than four years to complete. Our baseline sample came from the Cooperative Institutional Research Program’s (CIRP) 2004 Freshman Survey (TFS), which was administered by the Higher Education Research Institute (HERI). The TFS asked freshman students about their demographic characteristics and academic backgrounds, their high school activities, their educational and career ambitions, and expectations of college. The National Institutes of Health (NIH) provided funds to target minority-serving institutions and institutions with NIH-sponsored undergraduate research programs to expand the traditional sample of colleges and universities that participate in the TFS. These funds provided an opportunity to administer the TFS to campuses that typically do not collect such data on their students.

In 2010 we collected degree and enrollment data for this baseline sample from the National Student Clearinghouse (NSC). The NSC has collected enrollment and completion data on students for 15 years, and currently more than 3,700 colleges and universities in the U.S. provide data to the NSC. These data from the NSC provided information about students’ enrollment patterns, whether they completed a degree within five years of enrollment, and the discipline of their degree. Merging respondents from the 2004 TFS with data from the NSC resulted in a dataset containing 210,056 first-time, full-time students from 361 colleges and universities. From this sample, we removed students for whom the NSC did not provide degree information and identified all students who reported on the 2004 TFS that they intended to major in an engineering discipline (see Appendix A for all engineering majors), resulting in a sample of 16,298 students across 305 four-year colleges and universities.

To supplement the student-level data, we incorporated institutional data from the 2011 Best Practices Survey (BPS), the 2007 and 2010 CIRP Faculty Surveys, and the Integrated Postsecondary Educational Data System (IPEDS). In 2011, HERI researchers administered the BPS to STEM deans and department chairs at institutions in our student sample, which collected information about the extent to which campuses provided undergraduate research opportunities, outreach and retention programs to targeted groups, faculty development programs for STEM faculty, and the funding sources of these programs. We aggregated data from the 2007 and 2010 administrations of the CIRP Faculty Survey to provide contextual information about faculty attitudes and instructional strategies on each campus during the time period of the study. Additionally, we merged in institutional characteristics from IPEDS, which provides the most comprehensive data available on higher education institutions in the U.S.

The combination of these various student- and institutional-level datasets provided a large, unique, and unprecedented dataset to examine engineering completion. After accounting for non-response to the BPS and faculty surveys, our final analytic sample included 15,913 engineering aspirants across 270 four-year colleges and universities.

Variables

Student-level characteristics. The dependent variable in this study was a three-part categorical variable corresponding to students' degree status five years after enrolling in college: completed an engineering bachelor's degree, completed a bachelor's degree in a non-engineering field, or had not completed a degree. We derived this dependent variable from NSC data by cross-referencing students' bachelor's degree status (i.e., graduated or not graduated) with their bachelor’s degree major. In the analyses, we used “completed an engineering degree” as the reference group so that we can compare engineering degree graduates to non-engineering graduates and to students who were either still enrolled or had left their original institution. Thus, the dependent variables model potential institutional accountability for engineering productivity.

The analyses accounted for several student-level independent variables, including demographic characteristics, prior academic preparation, educational and career aspirations, and pre-college experiences. (Appendix B contains the variable and scales in our analyses). Students’ racial or ethnic identification was included as prior research has shown that underrepresented racial minority students (i.e., African American, American Indian, and Latino) more often receive unequal academic preparation (Adelman, 2006; Elliott, Strenta, & Adair, 1996; May & Chubin, 2003) and face particular challenges in STEM programs (Chang, Eagan, Lin, & Hurtado, 2011). Other demographic variables included gender (given disparities in engineering completion, LeBeau et al., 2012), income, mother’s education level, whether either parent worked in an engineering occupation, and whether the student is a native English speaker. We measured prior academic preparation with several variables: high school GPA, standardized test scores (SAT composite with ACT equivalent conversions, rescaled so a one-unit increase corresponds to a 100-point increase in score), and the years of study students completed in high school in biological science and mathematics. We included several high school experiences in the model to examine the relationship between engineering completion and the frequency with which students felt overwhelmed by all they had to do, socialized with a student from a different racial or ethnic group, the hours per week they spent studying or doing homework in high school, and whether the student participated in a pre-college summer research program.

We also examined a set of aspirations and expectations students had upon enrolling in college. We included whether they expected to transfer to another institution as an indicator of initial student commitment. Additionally, the model accounted for two constructs representing students' academic self-concept and social self-concept at college entry, which were developed using Item Response Theory techniques (see Sharkness et al., 2010). The model included dummy variables representing students' degree aspirations for a health professional degree (i.e., MD, DOO, DVM, etc.), Ph.D. or Ed.D., master's degree, and law degree with bachelor's degree or less as the reference group. Given Carlone and Johnson's (2007) work on the importance of science identity, we included a factor representing students' STEM identity at college entry. We created this construct using principal axis factoring with promax rotation, and the items comprising this factor included the following four items: goal of wanting to make a theoretical contribution to science, wanting to be recognized as an authority in the field, wanting to be recognized for contributions to the field, and wanting to find a cure to a health problem. Chang et al. (2011) provide additional information about this factor and found a positive relationship between STEM identity and first-year biomedical and behavioral science major persistence. The final set of individual-level predictors included dummy variables representing students' specific engineering major, and mechanical engineering aspirants comprised the reference group.

Institution-level characteristics. The analyses also accounted for a number of institutional characteristics. For example, we control for institutional type, selectivity, and control. We measured selectivity as the average SAT scores (or ACT equivalent scores) of entering students in 2004 and re-scaled this variable so that a one-unit change corresponds to a 100-point change in average SAT scores. Additionally, we had three indicators of types of minority-serving institutions to compare them to predominantly White institutions (PWI):

HBCU, Hispanic-Serving Institution (HSI, with 25% or more of undergraduate enrollment identifying as Hispanic), and emerging HSI (with Hispanic students comprising 15-24% of undergraduate students). The model included dummy variables representing institution type including research institution, liberal arts institution, with master's comprehensive serving as the reference. We also examined the predictive power of institutional size (undergraduate FTE enrollment) and the concentration of undergraduate STEM students on campus. A final structural characteristic in the model was total expenditures per full-time equivalent student.

To provide information about how completion in STEM may be influenced by the faculty campus context, we aggregated several variables from the 2010 and 2007 CIRP Faculty Survey. Given the importance of authentic discovery experiences in college (PCAST, 2012), we examined the relationship between engineering completion and the percentage of STEM faculty who involve undergraduate in their research. Additionally, we considered aggregate STEM faculty pedagogical practices, including the proportion of STEM faculty who grade on a curve and faculty's use of student-centered pedagogy. The latter represents a construct of several items describing professors' instructional strategies in the classroom (See Higher Education Research Institute, 2011), including faculty's use of class discussions, cooperative learning, experiential learning, and group projects, among other techniques.

In addition to data from IPEDS and the CIRP Faculty Survey, we aggregated variables from the student data and incorporated measures from the BPS survey reported by deans and department chairs. From the BPS survey, we included four items in the model representing the extent to which institutions offered undergraduate research opportunities to all freshmen, provided targeted financial aid to STEM students, offered internships and co-ops to students, administered high school STEM outreach programs, and provided research opportunities to all undergraduates. To capture the peer environment, using the student data, we created a measure representing the proportion of students in STEM aspiring to a health professional degree.

Analyses

Before handling cases with missing data or running univariate or multivariate statistics, we weighted the data to represent a national sample of full-time, first-time entering engineering aspirants in 2004. This weighting scheme involved a three-step process. First, we weighted students within institutions by gender so that the male and female respondent counts matched the population of first-time, full-time men and women within each institution in 2004. Second, to address non-participation by certain types of institutions in the U.S., we weighted by gender within each stratification cell. Finally, the two weights were multiplied so that, when applied to the data, the weighted sample represented the population of first-time, full-time students who entered college in the U.S. in 2004. See DeAngelo et al. (2011) for additional information about the weighting procedure).

After weighting the data, we addressed cases with missing values by using multiple imputation. Missing data provide a source of variation (Sinharay, Stern, & Russell, 2001), and providing a single imputation for missing values does not account for this possible variance. Little and Rubin (2002) suggest that multiple imputation provides a more precise estimate of standard errors of parameter estimates. We used the multivariate normal approach available in STATA 11 to execute the multiple imputation procedure. DeAngelo et al. (2011) provide additional details about the multiple imputation procedure.

We examined our data with univariate descriptive statistics after addressing issues with missing data. Next, we analyzed the data using multinomial hierarchical generalized linear modeling (HGLM). Multinomial HGLM represented the most appropriate analytic technique given our categorical, unranked outcome and the clustered nature of our data. Multinomial HGLM partitions the variance between individuals (i.e., students) and groups (i.e., institutions) in analyses with multi-level data and a categorical outcome variable (Raudenbush & Bryk, 2002). Studies that employ single-level statistical techniques, such as logistic regression, on multi-level data do not account for the unique clustering effect of the complex sample design, which increases the risk of making a Type I statistical error by erroneously concluding the significance of a parameter estimate (Raudenbush & Bryk).

To justify the use of multinomial HGLM, the outcome variable must vary significantly across groups. We examined the null model (i.e., model without any independent variables) to determine the extent to which five-year engineering completion varied across institutions. The null model showed that the between-institution variance component in the outcome significantly varied across institutions. Given this significant variation and our interest in the examining how institutional contexts both directly affect students' engineering completion likelihood and moderate individual-level relationships, we proceeded with the use of multinomial HGLM.

Limitations

While the longitudinal assessment of engineering degrees is extremely useful, several limitations are in order. First, the grouping of science, technology, and math degree completers with non-STEM degree completers under the non-engineering completers category may influence the results. For example, in the model comparing engineering completers with non-engineering completers, some of the critical STEM programs and resources that are not found to be significant may be related to the grouping in the dependent variable. Some may be confounded by these results as it may suggest that these programs and resources are not important for engineers, however, it may instead indicate that these resources do not impact the five-year degree completion of engineers any differently than students in other science majors. A second limitation is that the 2010-11 NCS data did not capture students' term-to-term academic major. NCS is beginning to collect such information now, which will allow improved accuracy of understanding the mobility and sustained commitment to engineering among students in higher education.

A third limitation is that, ideally, longitudinal studies will include college experience data. Other college experience studies have used smaller scale datasets to examine retention in STEM (Chang et al., 2010; Espinosa, 2011), but the downside is that data could only be collected to the fourth year of college; thus, with a smaller sample size, it becomes more difficult to identify differences by race/ethnicity and intended major. Instead, we have opted to capture conditional effects based on institutional differences with a larger sample size. Additionally, this approach allows us to examine engineering completion compared to completing a degree in a non-engineering field and to not completing a bachelor's degree. The present study focused on the individual level and macro-level phenomenon in Bronfrenbrenner's framework and provides a substantial backdrop for investigating meso-level experiences with faculty and peers, in and out of the classroom, and program effects in the future.

The study is also limited by its use of secondary data analysis, as we are limited by the variables and their definitions on the 2004 CIRP Freshman Survey. Specifically, the 2004 Freshman Survey lacked important measures of academic preparation, including the types of math courses taken and the extent to which students completed Advanced Placement or honors courses in high school. Additionally, 89% of Deans and Department chairs responded to the BPS survey and approximately 20 institutions did not participate in either of the HERI Faculty

Surveys, which required us to eliminate 35 campuses and 385 students from our initial engineering student sample.

Finally, because we surveyed all STEM deans and department chairs within our institutional sample, we had many institutions that contained more than one response about the extent to which they provided various opportunities to students and faculty. Given the potential variation with these responses within institutions, we conducted sensitivity analyses in our statistical modeling. We analyzed three separate institutional models: the lowest value for each BPS response within an institution; the average value for each BPS response within each institution; and the largest value for each BPS response within each institution. We found similar results across the three different datasets (least, average, greatest); thus, the results we report in our findings correspond to the model choosing the average values from the BPS variables.

Results

Descriptive statistics

Descriptive statistics show that among all engineering aspirants, 35.2% earned an engineering degree within five years while about a quarter (24.6%) completed a degree in another field and 40.1% had not completed a degree (see Appendix C for descriptive statistics). The vast majority of students in our sample were male; only 16.88% were female, further highlighting the severe underrepresentation of women in engineering. Most of the students in our sample were also White (66.88%); 13.93% indicated Asian or Pacific Islander, 8.91% were Black, 7.13% were Latino/a, 1.63% were American Indian, and 1.52% described their race as "other."

Among the sample of engineering aspirants, the major to which most aspired was mechanical engineering (25.53%), followed by computer engineering (15.85%), electrical or electronics engineering (13.50%), civil engineering (11.63%), aeronautical or astronautical engineering (9.02%), chemical engineering (7.54%), and industrial engineering (2.73%). The remainder (14.24%) chose “other engineering.” Finally, the sample of engineers showed strong high school academic performance. The average SAT score for the sample was 1205, and students took four years of math and two years of physical sciences on average while in high school.

Engineering Completion Versus Completion in a Non-Engineering Field

Table 1 displays the results of the multinomial hierarchical generalized linear model (HGLM) identifying variables that contribute to the probability of an engineering aspirant completing an engineering degree in five years as opposed to switching and completing in another field. We present and interpret the results in a manner that higher scores on the independent predictors reflect increased probability of completing a degree in engineering. We also only report delta-p statistics for those variables significant at the $p<0.05$ level (citations).

First, four institutional characteristics were significant in the model. Engineering students who attend private colleges and universities are 21.88% more likely to complete their degree in engineering in five years than students at public institutions. Students at larger institutions are also more likely to complete in engineering, and students at institutions with a higher proportion of STEM faculty who engage undergraduates in research are more likely to complete in engineering as well. Surprisingly, engineering aspirants at colleges and universities where STEM faculty are more likely to utilize student-centered pedagogy are less likely to complete a degree in engineering within five years—specifically, for every one-unit increase in an institution’s average score among STEM faculty on a student-centered pedagogy construct, students’ likelihood of completing in engineering drops by 27.83%. As this variable is an aggregated measure of STEM faculty who participated in the faculty surveys, several issues may confound the results and interpretation. First, it may very well be that schools that graduate more engineers are also schools where STEM faculty use student-centered pedagogical practices less often. Second, it is possible that the STEM faculty who use student-centered pedagogical practices are not within engineering departments, which may sway engineering aspirants into science or math programs. Third, it is also possible that the aggregated measure on the student-centered pedagogy construct among STEM faculty who participated in the faculty surveys may not be representative of the pedagogical practices used by other STEM faculty within an institution. Thus, it may be that many institutions appear to be using student-centered pedagogy at higher rates because of the STEM faculty who responded to the surveys, yet may actually not be using student-centered pedagogy more often if our surveys were able to capture more STEM faculty within all institutions.

Two student background characteristics significantly affect engineering students' probability of completing their degrees in engineering. Gender plays a role in that women (7.42%) are more likely than men to switch and complete in another field. Parental influence is also important in that students who have at least one parent employed as an engineer are 5.71% more likely to complete in engineering as opposed to another field. No significant differences were observed for race/ethnicity, income, mother's level of education, or whether a student is a native English speaker.

High school academic performance is also a significant predictor of completing in engineering as opposed to another field. A one-point increase in high school GPA increases engineering students' probability of completing in engineering in five years by 4.82%, and a one hundred point increase in SAT score increases their probability by 3.53%. In addition to performance, high school academic behaviors also matter: students who spent more time studying or doing homework in high school are more likely to complete in engineering.

Engineering students' entering expectations for college and concepts of self also affect their likelihood of completing in engineering. Students with a higher sense of STEM identity are more likely to complete in engineering in five years as opposed to completing in another field. Both academic and social self-concept were also significant in the model: a one standard deviation increase in academic self-concept increases students' likelihood of completing in engineering by 3.31% while a one standard deviation increase in social self-concept decreases students' likelihood of completing in engineering by 2.34%.

Finally, we examined differences among various engineering degree programs, using mechanical engineering, the most popular engineering major, as a reference group. Civil engineering students are no more or less likely than mechanical engineering students to complete in engineering. The other fields represented in this study are all less likely to complete in engineering than mechanical engineering students, however. Aeronautical and astronautical engineering students are 15.21% less likely, chemical engineering students are 9.07% less likely, computer engineering students are 27.46% less likely, electrical and electronics engineering students are 4.54% less likely, industrial engineering students are 17.93% less likely, and students in engineering fields designated as “other” are 15.53% less likely to complete in engineering. There are significant differences across fields in terms of requirements and coursework, many of which are reflected in these differences in persistence. These numbers do not reflect students who switch engineering programs, though, as these categories only reflect the degrees to which students aspired when they entered college, and the outcome variable is completion of any engineering degree.

Engineering Completion Versus No Completion

Table 1 also displays the results of our multinomial HGLM analysis for engineering completion in five years compared to not completing a degree at all. Engineering students at private institutions are 30.47% more likely to complete an engineering degree as opposed to not complete than their peers at public institutions. Engineering students at more selective schools are also more likely to complete an engineering degree; for every 100 point increase in the average SAT score of an institution there is a 14.94% increase in the probability of completing an engineering degree in five years compared to not completing. Also, an increase in an institution’s average score among STEM faculty on the student-centered pedagogy construct corresponds with a decrease engineering students’ likelihood of completing an engineering degree. This could, as mentioned earlier, simply reflect some of the issues related to the fact that an institution’s average score among STEM faculty on the student-centered pedagogy construct is an aggregated measure of STEM faculty who participated in the surveys. Finally, engineering students at larger institutions and at institutions where more STEM faculty engage undergraduates in research are more likely to complete an engineering degree in five years than not complete, similar to our model predicting probability of switching out of engineering.

Student background characteristics also influence their likelihood of completing an engineering degree. Native American engineering aspirants are 14.77% less likely than White students to complete an engineering degree in five years, and Latino engineering aspirants are 9.69% less likely to complete an engineering degree in five years. Women are 7.78% more likely, however, than men to complete an engineering degree in five years, and students with one or more parents employed as an engineer are 6.65% more likely to complete an engineering degree in five years.

Socioeconomic indicators are also significant factors affecting students' likelihood of completing engineering degrees. Compared to middle income students, students from high-middle income backgrounds are 3.14% more likely to complete an engineering degree, and students from low income backgrounds are 4.72% less likely to complete an engineering degree in five years. Students whose mothers have a higher level of education are also more likely to complete an engineering degree in five years.

High school academic preparation also influences the likelihood that engineering aspirants complete engineering degrees as opposed to not completing. A one-point increase in high school GPA increases the likelihood of five-year engineering degree completion by 12.85% and a 100-point increase in SAT score increases the likelihood by 3.84%. Taking more years of high school math also increases the likelihood of five-year engineering degree completion compared to no completion. Several high school experiences also predict a higher likelihood that engineering aspirants complete engineering degrees in five years. Students who reported a higher frequency of socializing with others of different racial or ethnic backgrounds are less likely to complete engineering degrees whereas students who reported spending more time in high school studying or doing homework are more likely to complete engineering degrees.

Engineering aspirants' entering college aspirations and expectations also affect their chances of completing an engineering degree in five years. A one standard deviation increase in academic self-concept increases students' chances of completing an engineering degree in six years by 3.02%. Students who aspire to a doctoral degree are 7.71% less likely to complete an engineering degree in five years than their peers who aspire to a bachelor's degree or less; this is not surprising given an engineering bachelor's degree is the first professional degree for an engineering career. Students who plan to live on campus are 8.01% more likely to complete an engineering degree than their peers who do not. This finding confirms prior research that has linked living on campus with increased retention and persistence.

Finally, we also observed differences among different engineering degree fields in terms of students' likelihood of completing an engineering degree in five years as opposed to not completing a degree. Aeronautical and astronautical engineering students are 7.38% less likely, civil engineering students are 5.99% more likely, and computer engineering students are 15.54% less likely to complete an engineering degree in five years than mechanical engineering students. Just as was observed for the probability of engineering degree completion compared to non-engineering completion, there are significant differences among engineering degree fields in terms of students' likelihood of completing an engineering degree compared to not completing a degree at all. Much of these differences may be attributable to differences in degree requirements and rigor of coursework.

Conclusion and Implications

The purpose of this study was to identify contextual factors that contribute to five-year engineering degree completion. We controlled for several pre-college characteristics, attitudes, and aspirations in order to parse out the ways the college environment influences the likelihood that a student intending to major in engineering accomplishes this goal. Our model then compared this to the likelihood of both switching and completing in another field, and the likelihood of not completing altogether. From our analysis, we have identified several conclusions that hold important implications for engineering educators and institutional policymakers.

Our primary conclusion is that institutional context matters. A great deal of research on degree completion focuses on student-level variables such as attributes, behaviors, or experiences, or on programmatic-level interventions such as pedagogical practices or co-curricular programs, typically at a single institution. Studies like these are unable to capture the variation across institutions and thus identify some of the ways different types of institutions are uniquely positioned to support degree completion. We found several institutional characteristics significantly influenced the likelihood of engineering degree completion, some of which supported prior research and some of which was unique to our examination of engineering students. Policymakers and educators benefit from understanding how these factors affect degree completion because they shape institutional culture.

One contribution from our analysis is how the individual practices of faculty can aggregate into an institutional influence on engineering persistence. For example, the greater the proportion of STEM faculty who engage undergraduates in research, the more likely students complete engineering degrees. While many studies have been able to show the impact at the student level that participation in programs like these has on individual student persistence, there is also a discernible impact of this mesosystem experience on the broader institutional macrosystem. In addition, though the variable is not focused on engineering faculty specifically, the effect is observed with this sample of engineering aspirants. In considering co-curricular programs like undergraduate research as mesosystems, our theoretical framework calls attention to how they may serve as a connection between microsystems, such as different STEM fields. Our data do not demonstrate that participating in undergraduate research directly improves an engineering aspirant’s chances of completing an engineering degree, but that encouraging more faculty to engage in this activity can benefit students in indirect ways.

Contrary to prior literature, in both models the greater the proportion of STEM faculty who used student-centered pedagogies, the less likely engineering aspirants were to complete engineering degrees. Or, taken another way, at institutions where more STEM faculty used student-centered pedagogies, the more likely engineering aspirants were to either switch to other fields or to not complete degrees altogether in five years. Given the extant literature that demonstrates student-centered pedagogies not only improve engineering students' academic outcomes (Felder, Felder, & Dietz, 1998; Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012), but also for college students across the board, we do not take our findings to mean that there is some indirect detriment these practices have for engineering students in aggregate. Rather, given that STEM faculty are less likely to use student-centered teaching practices compared to faculty in other fields (Hurtado, Eagan, Pryor, Whang, & Tran, 2012), these findings are likely due to issues related to the fact that an institution's average score among STEM faculty on the student-centered pedagogy construct is an aggregated measure of STEM faculty who participated in the surveys. Taken together with the finding that engineering aspirants at larger colleges are more likely to complete engineering degrees, again, in contradiction to prior research (Hurtado, Eagan, & Hughes, 2012; Oseguera, 2005), these findings are less an indictment of the effectiveness of engineering faculty in implementing student-centered pedagogy and more an indication that engineering faculty who use student-centered pedagogies are a smaller minority at institutions with larger engineering programs. Further research is needed to better understand the use of student-centered pedagogical practices within engineering departments specifically and among colleges that graduate greater numbers of engineering students.

Finally, our data allowed us to explore differences among engineering fields in terms of how disciplinary cultures and expectations may affect persistence to an engineering degree. First of all, students in all fields except civil engineering were more likely to complete outside of engineering than mechanical engineering aspirants. Civil engineers were also less likely to not complete in five years than mechanical engineers. Computer engineering demonstrated the greatest difference from mechanical engineering in terms of switching out of engineering or not completing a degree. Each of these programs requires different skills and competencies, and students are drawn to each for a diverse range of reasons. For instance, computer engineering is extremely lucrative today given the number of technology and start-up companies that demand these skills. Many students may be drawn to computer engineering due to perceived ease of employment and high salary but lack the requisite skills, or students with computer engineering skills are recruited by start-ups away from college and no longer need to earn the credential of a bachelor's degree.

Given that increasing the number of engineers in our country's workforce continues to be a pressing national need, understanding institutional factors that contribute to the environment that fosters engineering talent development is of utmost concern to our nation's higher education systems. This study set out to identify some of these characteristics that better position different colleges or universities to graduate higher proportions of their engineering aspirants in engineering degrees. Taking into consideration how an institution's unique culture and mission affect engineering degree completion better informs policy efforts to improve degree productivity as well as assists faculty and other engineering educators to craft programs and interventions that support the needs of students and develop their potential to succeed as professional engineers.

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Appendix A

List of Engineering Majors

1. Aeronautical/Astronautical Engineering
2. Civil Engineering
3. Chemical Engineering
4. Computer Engineering
5. Electrical Engineering
6. Industrial Engineering
7. Mechanical Engineering
8. Other Engineering

Appendix B
Table of Measures

	Variable Name	Coding Scheme
Dependent Variable		
	Engineering Completion	1=Completed bachelor's degree in Engineering; 2=Completed bachelor's degree in a non-Engineering field; 3=Did not complete a bachelor's degree (measured at 5 years)
Institutional Characteristics		
	Percentage of pre-med students (10)	Continuous
	Control: Private	1=public, 2=private
	Institutional type: Research (ref. masters comp.)	0=no, 1=yes
	Institutional type: Liberal arts (ref. masters comp.)	0=no, 1=yes
	Percentage of undergraduates in STEM (10)	Continuous
	HBCU	0=no, 1=yes
	Emerging HSI (15-24% of undergraduates are Latino)	0=no, 1=yes
	HSI (25% or more of undergraduates are Latino)	0=no, 1=yes
	Undergraduate FTE enrollment (log)	Continuous
	Percentage of STEM faculty involving undergraduates in research	Continuous
	Average extent that STEM faculty grade on a curve	Continuous
	Avg. STEM faculty score on student-centered pedagogy construct	Continuous
	Selectivity (100)	Continuous
	Institution offers undergraduate research opportunities to freshmen	0=not at all to 2=to a great extent
	Institution provides targeted financial aid to STEM students	0=no, 1=yes
	Institution has high school STEM outreach programs	1=not at all to 3=to a great extent
	Institution offers undergraduates research opportunities	1=not at all to 3=to a great extent
	Institution offers internships and cooperative experiences	1=not at all to 3=to a great extent
	Institutional expenditures per FTE student	Continuous

Background Characteristics	
Native American	0=no, 1=yes
Black	0=no, 1=yes
Latina/o	0=no, 1=yes
Asian American or Pacific Islander	0=no, 1=yes
Other Race	0=no, 1=yes
Sex: Female	1=male, 2=female
Low Income (Under $25K)	0=no, 1=yes
Low-middle income ($25K to $49,999)	0=no, 1=yes
High Middle Income ($100K-$199,999)	0=no, 1=yes
High Income ($200K+)	0=no, 1=yes
Student Native English Speaker?	0=no, 1=yes
Mother's education	1=grammar school or less to 8=graduate degree
Either parent has an engineering occupation	0=no, 1=yes
Prior Preparation	
Average High School Grade	1=D to 8=A or A+
SAT composite score	Continuous
Years of HS study: Math	1=None to 7=Five or more
Years of HS study: Biological sciences	1=None to 7=Five or more
Pre-College Experiences	
Felt Overwhelmed by All I Had to Do	1=not at all to 3=frequently
Socialized w/Diff Ethnic Group	1=not at all to 3=frequently
Hours Per Week in High School: Studying or Homework	1=none to 8=over 20 hours
Participated in a pre-college summer research program	0=no, 1=yes
Entering Aspirations and Expectations	
Transfer to Another College	1=no chance to 4=very good chance
Academic self-concept construct	Continuous
Social self-concept construct	Continuous

Medical Degree Aspiration	0=no, 1=yes
Masters Degree Aspiration	0=no, 1=yes
Ph.D./Ed.D. aspiration	0=no, 1=yes
Law Degree Aspiration	0=no, 1=yes
Plan to live on campus	0=no, 1=yes
STEM Identity	Continuous
Intended Major	
Aeronautical/Astronautical Engineering major (ref: Mechanical)	0=no, 1=yes
Civil Engineering major (ref: Mechanical)	0=no, 1=yes
Chemical Engineering major (ref: Mechanical)	0=no, 1=yes
Electrical/Electronics Engineering major (ref: Mechanical)	0=no, 1=yes
Industrial Engineering major (ref: Mechanical)	0=no, 1=yes
Other Engineering Major (ref: Mechanical)	0=no, 1=yes

Appendix C

Descriptive Statistics

	Mean	S.D.	Min	Max
Institutional Characteristics				
Percentage of pre-med students	0.24	0.12	0	0.62
Control: private	1.67	0.47	1	2
Type: Research (ref: masters comp)	0.24	0.43	0	1
Type: Masters comprehensive	0.41	0.49	0	1
Type: Liberal arts (ref: masters comp)	0.35	0.48	0	1
Percentage of undergrads in STEM	12.91	10.81	0	91.28
HBCU	1.05	0.21	1	2
Undergraduate FTE (log)	8.17	0.87	6.48	10.35
Percentage of STEM faculty engaging undergrads in research	1.59	0.24	1	2
Percentage of STEM faculty who grade on a curve	1.82	0.46	1	4
Average STEM faculty score on student-centered pedagogy construct	-0.02	0.4	-1.46	1.34
Selectivity (100)	11.23	1.46	0	15.1
Institution offers undergraduate research opportunities to freshmen	1.7	0.45	0	2
Institution offers targeted financial aid to STEM students	0.89	0.29	0	1
Emerging HS I	0.04	0.2	0	1
HS I	0.04	0.2	0	1
Institution has high school STEM outreach programs	1.98	0.59	1	3
Institution offers undergraduate research opportunities	2.56	0.55	1	3
Institution offers internship or co-operative education programs	1.93	0.58	1	3
Expenditures per FTE	34.24	65.22	9.19	972.01
Background Characteristics				
Low income (under $25K)	0.08	0.28	0	1
Low-middle income ($25K - $49,999)	0.15	0.36	0	1
Middle income ($50K - $99,999)	0.38	0.48	0	1
High-middle income ($100K - $199,999)	0.29	0.45	0	1
High income ($200K+)	0.09	0.29	0	1
Native English speaker	0.9	0.29	0	1
Mother's level of education	5.51	1.82	1	8
Either parent employed as an engineer	0.17	0.37	0	1
Prior Preparation				
Average high school GPA	6.74	1.29	1	8
Final SAT composite or converted ACT	1227.81	166.28	440	1600
Yrs of study in HS: Math	6.08	0.52	1	7
Yrs of study in HS: Biology	3.39	0.85	1	7
Pre-college Experiences				
Felt overwhelmed by all I had to do	1.96	0.61	1	3
Socialized with different racial/ethnic group	2.65	0.54	1	3

Hrs per wk in HS: Studying or homework	4.2	1.57	1	8
Pre-college summer research experience	0.09	0.28	0	1
Entering Aspirations and Expectations				
Plan to transfer to another college	1.89	0.82	1	4
Academic self-concept	53.35	7.73	12.65	66.92
Social self-concept	47.82	9.27	18.06	68.14
Bachelors or less degress aspiration	0.27	0.44	0	1
Medical degree aspiration	0.04	0.19	0	1
Masters degree aspiration	0.48	0.5	0	1
Phd/EdD aspiration	0.19	0.39	0	1
Law degree aspiration	0.01	0.11	0	1
Plan to live on campus	0.86	0.35	0	1
STEM identity	-0.12	0.97	-2.22	2.22
Intended Major				
Aeronautical/astronautical engineering (ref: mechanical)	0.08	0.28	0	1
Civil engineering (ref: mechanical)	0.12	0.32	0	1
Chemical engineering (ref: mechanical)	0.08	0.27	0	1
Computer engineering (ref: mechanical)	0.15	0.35	0	1
Electrical/electronics engineering (ref: mechanical)	0.13	0.33	0	1
Industrial engineering (ref: mechanical)	0.03	0.16	0	1
Mechanical engineering	0.26	0.44	0	1
Other engineering (ref: mechanical)	0.16	0.37	0	1

Table 1

Results from Multinomial HGLM Analysis on Completion of an Engineering Degree

	Versus non-engineering completion				Versus no completion			
	Coef.	S.E.	Sig.	Delta-p	Coef.	S.E.	Sig.	Delta-p
Institutional Characteristics								
Intercept	-0.280	0.975			-1.410	1.106		
Percentage of pre-med students	-1.677	1.030			-1.215	1.177		
Control: private	0.894	0.368	*	21.88%	1.319	0.376	**	30.47%
Type: Research (ref: masters comp)	-0.171	0.278			-0.400	0.341		
Type: Liberal arts (ref: masters comp)	-0.291	0.334			-0.276	0.412		
Percentage of undergrads in STEM	0.026	0.013			-0.003	0.016		
HBCU	-0.819	0.648			-0.569	0.789		
Undergraduate FTE (log)	0.652	0.225	**	14.45%	0.834	0.280	**	20.15%
Percentage of STEM faculty engaging undergrads in research	1.071	0.493	*	21.83%	1.309	0.545	*	29.73%
Percentage of STEM faculty who grade on a curve	-0.003	0.240			0.038	0.305		
Average STEM faculty score on student-centered pedagogy construct	-1.157	0.247	***	-27.83%	-1.036	0.283	**	-22.99%
Selectivity (100)	0.143	0.168			0.606	0.182	**	14.94%
Institution offers undergraduate research opportunities to freshmen	0.313	0.279			0.073	0.307		
Institution offers targeted financial aid to STEM students	-0.021	0.279			-0.221	0.432		
Emerging HS I	0.351	0.446			0.291	0.325		
HS I	0.201	0.408			0.795	0.462		
Institution has high school STEM outreach programs	0.114	0.164			0.078	0.204		
Institution offers undergraduate research opportunities	-0.403	0.214			-0.389	0.250		
Institution offers internship or co-operative education programs	0.181	0.170			-0.035	0.212		
Expenditures per FTE	-0.001	0.001			0.000	0.002		
Background Characteristics								
American Indian	-0.238	0.213			-0.611	0.199	**	-14.77%
Black	-0.916	0.683			-1.538	0.920		
HBCU	0.806	0.584			0.856	0.815		
Latino/a	0.057	0.118			-0.393	0.128	**	-9.69%

Asian/Pacific Islander	-0.006	0.088			0.160	0.109		
Other race	-0.066	0.187			0.215	0.181		
Sex: Female	-0.302	0.063	***	-7.42%	0.312	0.068	***	7.78%
Low income (under $25K)	-0.046	0.091			-0.191	0.093	*	-4.72%
Low-middle income ($25K - $49,999)	-0.051	0.074			-0.124	0.079		
High-middle income ($100K - $199,999)	-0.002	0.054			0.126	0.051	*	3.14%
High income ($200K+)	-0.119	0.084			0.052	0.094		
Native English speaker	-0.128	0.126			0.011	0.131		
Mother's level of education	0.016	0.016			0.057	0.013	***	1.43%
Either parent employed as an engineer	0.240	0.059	***	5.71%	0.266	0.058	***	6.65%
Prior Preparation								
Average high school GPA	0.203	0.033	***	4.82%	0.519	0.029	***	12.85%
Final SAT composite or converted ACT (100)	0.148	0.030	***	3.53%	0.154	0.026	***	3.84%
Yrs of study in HS: Math	0.091	0.053			0.117	0.051	*	2.93%
Yrs of study in HS: Biology	0.024	0.042			0.026	0.032		
Pre-college Experiences								
Felt overwhelmed by all I had to do	-0.043	0.043			-0.051	0.043		
Socialized with different racial/ethnic group	0.035	0.054			-0.179	0.057	**	-4.42%
Hrs per wk in HS: Studying or homework	0.078	0.016	***	1.88%	0.148	0.021	***	3.70%
Pre-college summer research experience	0.007	0.083			-0.077	0.074		
Entering Aspirations and Expectations								
Plan to transfer to another college	-0.069	0.041			-0.037	0.034		
Academic self-concept (10)	0.139	0.056	*	3.31%	0.121	0.053	*	3.02%
Social self-concept (10)	-0.096	0.029	**	-2.34%	-0.067	0.034		
Medical degree aspiration	-0.086	0.193			-0.226	0.222		
Masters degree aspiration	-0.007	0.061			-0.099	0.063		
Phd/EdD aspiration	-0.050	0.085			-0.311	0.091	**	-7.71%
Law degree aspiration	-0.324	0.198			-0.310	0.243		
Plan to live on campus	-0.119	0.119			0.326	0.093	**	8.01%
STEM identity	0.076	0.028	**	1.82%	0.032	0.029		
Intended Major								

Aeronautical/astronautical engineering (ref: mechanical)	-0.646	0.166	***	-15.21%	-0.298	0.135	*	-7.38%
Civil engineering (ref: mechanical)	-0.161	0.128			0.240	0.104	*	5.99%
Chemical engineering (ref: mechanical)	-0.396	0.100	***	-9.07%	-0.001	0.112		
Computer engineering (ref: mechanical)	-1.140	0.117	***	-27.46%	-0.644	0.095	***	-15.54%
Electrical/electronics engineering (ref: mechanical)	-0.203	0.097	*	-4.54%	-0.032	0.099		
Industrial engineering (ref: mechanical)	-0.755	0.247	**	-17.93%	-0.092	0.263		
Other engineering (ref: mechanical)	-0.659	0.112	***	-15.53%	-0.145	0.108		