AC 2011-769: PREDICTING GRADUATE SCHOOL PLANS BASED ON STUDENTS' SELF-ASSESSED ENGINEERING KNOWLEDGE AND SKILLS

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Predicting Graduate School Plans Based on Students' Self-assessed Engineering Knowledge and Skills

Abstract

U.S. production of STEM graduates receiving master's and Ph.D. degrees has remained mostly constant in the last 50 years. With concern over the lack of domestic workforce in engineering graduate schools, recent studies have examined whether engineering seniors plan to attend graduate school in engineering, but there is little research on what affects undergraduates' decisions regarding graduate attendance plans inside or outside engineering. To measure the likelihood of graduate school attendance three years after they graduate, three sub-scales are employed: 1) will be in graduate school to become engineering faculty; 2) will be in engineering graduate school to prepare for the profession; and 3) will be in non-engineering graduate school (business, medicine, law, etc.). In this paper, I explore how students' gender, race/ethnicity, math proficiency prior to college, and confidence in fundamental skills and professional skills (leadership, communication, and teamwork skills) influences graduate school plans. Results from this study indicate that engineering students' fundamental skills are positively related to engineering graduate school plans, whereas leadership skills are negatively associated with them. Communication and teamwork skills positively influence graduate school plans inside or outside engineering. Women are more likely than men to plan to pursue engineering graduate school to prepare for an academic career as well as graduate school for other fields. This paper contributes to engineering educators' understanding of the factors that influence the actual choice of graduate school plans by students, and provides faculty members the information necessary to recruit more highly-qualified engineering students to engineering graduate school.

Introduction

Maintaining a competitive lead in science, technology, mathematics, and engineering (STEM) education has proven to be a challenge for the United States despite significant efforts to improve the recruitment and retention of STEM students. Fears of increasing global competition compound the perception that there has been a large decline in the supply of human resources in the STEM graduate education. Many other countries are increasing the number of STEM graduates who receive master's and Ph.D. degrees, while U.S. production has remained mostly constant in the last 50 years[1]. Instead of increasing domestic human resources, the nation has relied heavily on imports of well-educated college graduates from other countries to compensate for the loss of advanced degrees and jobs in science and engineering. Noting that the rates of foreign enrollments in graduate programs in science and engineering have increased by just three percent[2], however, Bowen, Chingos, McPherson, & Tobin contend that it is myth that the United States can continue to rely on the inflow of talent from overseas[3].

Both engineering graduate schools and industry have been requesting a diverse workforce to meet the needs of a diverse population[4]. However, there continue to be gender and race/ethnicity disparities in engineering doctoral degree attainment. For example, women earned 20% of engineering doctorates in 2006, although up from 12% in 1997, but still remain underrepresented in most engineering disciplines[1]. The proportion of engineering doctorate degrees awarded to underrepresented minority (URM) students is more daunting. Hispanic U.S.

citizen doctorate recipients averaged 5% from 1997 to 2006, with Black U.S. citizen and American Indian/Alaska Native doctorate recipients almost nonexistent during that period[1]. Despite the overall increase of URM students in higher education, the numbers lag far behind White and Asian male student groups in engineering programs and the workforce.

Post-graduate plans: engineering career and graduate school plans.

There is rationale for increasing the flow of students into engineering programs which, in turn, is assumed to produce more engineers[5]. However, several studies have demonstrated that majoring in engineering does not necessarily result in an engineering career or graduate study in the field. Lowell and Salzman found that two years after graduation from science and engineering programs, 20% of the graduates with bachelor's degrees were enrolled in non-science and engineering graduate programs and 45% were in the workforce – but not in science or engineering jobs[5]. Sheppard et al. also found that 25% of engineering seniors were considering both work and graduate school inside and outside of engineering, indicating that one in four seniors were unsure whether an engineering or non-engineering path would be the best fit for them[6].

Actual engineering graduate school enrollment is the most valid measure of graduate school attendance because graduate school plans might be different from the actual post-graduate outcomes. Still, understanding the factors that influence college students' career or graduate school plans upon graduation is an important focus for research because such plans are typically among the best predictors of actual choice of professions or graduate school enrollment [7 8 9 10]. Given one finding from a qualitative study that engineering students make plans to leave engineering *after* earning an undergraduate degree [11], there is a need to examine what factors contribute engineering students' post-graduate plans using large scale data sets. Such students may help undergraduate engineering programs design interventions to keep engineering students in the engineering graduate programs and profession.

Students' Self-assessments of Abilities and Graduate School Plans

Most research identifies academic preparedness in mathematics and science at an early age as one of the most salient factors influencing engineering student choice of graduate school in engineering[5]. However, Bandura argued that students aspire to careers based on not only their qualifications but also their self-efficacy in specific disciplines[12]. In his social learning theory [12], he proposed the concept of self-efficacy, which is defined as an individual's own perception of his or her ability to carry out the necessary actions to achieve a certain outcome[13]. For example, a student may have high ability in mathematics and science, but without self-efficacy, her career or graduate school choice may exclude engineering fields. Using Bandura's self-efficacy theories, Wang & Staver[14] and Wei-Cheng[15] found that career aspirations and interest in engineering disciplines during college seems to have an impact on persistence in engineering profession.

Additional research, however, is needed to understand how engineering undergraduates' self-assessed abilities affect their decisions regarding graduate school plans. Whereas some researchers have treated reports of self-efficacy as equivalent to self-estimated or -rated abilities[13, 16], others distinguish self-rated abilities from self-efficacy[17]. There are some similarities between these two constructs; both involve people's beliefs about their personal capabilities. However, Brown et al. argued that self-efficacy and self-rated abilities represent empirically related but distinct constructs[17]. They summarized this distinction, explaining that self-efficacy was assumed as prospective or future-oriented performance capabilities, whereas self-rated ability was focused on judgments about current abilities.

Although few researchers have explored whether students' self-ratings on their engineering skills contribute positively or negatively to their plans or intentions regarding graduate school attendance, theory and recent research support this hypothesis. Holland theorized that individuals choose occupations that are consistent with their vocational aspirations, interests, competencies, and self-rated abilities[18]. Exploring the relationships among interests, competencies, and self-rated abilities, Holland found positive correlations between students' scientific competencies and their interests in scientific occupations[18]. Because Holland examined only correlations, however, there is some ambiguity with respect to causal direction of the relationships between competencies and interests in occupations.

A recent study hypothesized that students' self-assessments of their knowledge and skills might influence their decisions to pursue an engineering career and graduate education. Sheppard, et al. found that senior students with greater confidence in their professional and interpersonal skills were less likely to head towards engineering careers or pursue engineering in graduate school[6]. We should use caution, however, when interpreting these results because the research design did not take into account students' confidence in other important engineering skills such as fundamental skills (e.g., mathematical, scientific, and technical knowledge and skill). Previous research supports that engineering and science students' confidence in fundamental skills encourages them to pursue graduate school in STEM fields. For example, examining factors that influence first-year college students' interests in pursuing science-related careers including graduate school, Astin and Astin found that the entering level of students' mathematical competency was the most powerful predictor of changes in interests in science careers[19]. Similarly, Sax found that self-ratings of math ability were a significant predictor of retention, which is presumed to influence persistence on paths to careers in engineering[20]. In an experiment with undergraduate students, Correll found that students who reported higher assessments of their own mathematical ability were more likely to pursue engineering and science careers than other counterparts[21]. Thus, research examining the impact of a broad array of skills rather than a focus on one set of skills is required.

In sum, scholars suggest that academic preparedness in mathematics and science, and good matches between qualifications and interest in engineering careers encourage engineering students to continue their graduate education in engineering programs. While these explanations may help demonstrate the choice of graduate fields, researchers have not yet considered the potential impacts of engineering students' confidence in a broad set of engineering skills on their graduate education plans. In this paper, I explored how students' confidence in a range of fundamental and professional skills (e.g., leadership, communication, and teamwork skills) influences graduate school plans as well as the. In addition, while previous studies have examined engineering and science students' plans for engineering graduate school, they have not determined whether those considering engineering graduate study are planning for academic or professional careers. I examined the impact of students' self-assessed abilities on graduate school plans leading to a career as an engineering faculty member; as preparation for work in the engineering profession; and for work outside engineering (business, medicine, law, etc.). Specifically, the research question is as follows:

> How do students' demographic characteristics (gender and race/ethnicity), math proficiency prior to college, and level of confidence in engineering knowledge and skills (fundamental, communication, teamwork, and leadership skills) influence their graduate school plans in engineering?

Method

Design, Population, and Sample

I employed data from the *Prototype-to-Production* (P2P) study which investigated curricular, instructional, and organizational practices and policies as well as the educational experiences of engineering alumni, in a nationally representative set of engineering programs. The institutional population was defined as all four-year engineering schools that offer two or more ABET-accredited programs in the "big five" engineering disciplines: chemical, civil, electrical, industrial, and mechanical as well as biomedical/ bioengineering and general engineering programs. The sampling frame was drawn from the American Society for Engineering Education's database using institution and program-level information on faculty and currently enrolled students. In the aggregate, these seven disciplines accounted for more than 70 percent of all baccalaureate engineering degrees awarded in 2007.

A 6x3x2 disproportional stratified random sample was drawn using the following strata: six discipline levels (general engineering programs were subsequently added to the sample), three levels of highest degree offered (bachelor's, master's, or doctorate), and two levels of "type of control" (public or private). The total sample of 32 four-year colleges and universities was "pre-seeded" with nine pre-selected institutions. These included the six case study institutions participating in a companion project *(Prototyping the Engineer of 2020*) and three institutions with general engineering programs. Penn State's Survey Research Center selected 25 additional institutions at random from the population within the 6x3x2 framework above. The final sample also included three historically black colleges and universities (HBCUs) and three Hispanic-serving institutions (HSIs). The sampling design ensured that the sample institutions are representative of the population with respect to type, mission, and highest degree offered.

Student Population and Sample

The four-year student population was defined as all sophomore, junior, and senior students in one of the focal engineering disciplines. Since some engineering programs do not allow students to declare a major until their sophomore year, the study's sample does not include first-year students. All students on each campus meeting the study's population specifications were invited to participate. Chi-square Goodness-of-Fit tests indicated that on some precollege student characteristics, respondents were marginally unrepresentative of the overall campus population of engineering students with respect to one or more of the following characteristics:

discipline, race/ethnicity, gender, or class level. The Chi-square test, however, is sensitive to large numbers. When comparing the population and sample distributions on these student characteristics, the proportions were relatively similar; differences between population and sample proportions ranged from 1% to 11%. Nonetheless, weights were developed to adjust for response bias (at the campus level) and for differences in institutional response rates. Weighting adjustments corrected for minor response biases, producing nationally representative samples for students with respect to sex, race/ethnicity, and engineering discipline. Consequently, the adjusted sample can be considered representative of the population of engineering students (as specified) both on each campus and nationally.

Data Collection Procedures and Response Rates

Institutions provided P2P project staff with electronic files containing contact information and student's gender, race/ethnicity, class year, and engineering field. In April 2009 and in advance of the first mailing, the dean of engineering on each campus e-mailed engineering students to advise them of the institution's participation in the study, alerting them that they would soon hear from the Penn State research group, summarizing the potential benefits to the campus, and encouraging them to participate in the study. The Penn State Survey Research Center (SRC) conducted all data collection for the student survey. SRC e-mailed or mailed an invitation to complete either a web-based or paper version of the survey instrument. Two weeks after the initial contact, non-respondents received e-mail or mail reminders. After an additional two weeks, non-respondents received a final e-mail or mail request with a copy of the paper version of the survey. SRC removed all personally identifying information from the dataset before releasing it to the research team.

Invitations to participate went to 32,737 students and 5,249 responded (16.4% response rate). Missing data were imputed using procedures recommended by Dempster, Laird, and Rubin [22] and by Graham [23]. Project staff imputed all missing data using the Expectation-Maximization (EM) algorithm of the Statistical Package for the Social Sciences (SPSS) software (v.18). Given this study is interested in students' post-graduate plans, only senior and higher year students are included in this study. Analyses are based on responses from 2,263 seniors and higher year students in 30 colleges of engineering during the 2009 spring and summer terms.

Scale Development and Variables Used

The P2P research team completed a series of factor analyses to provide a more compact, aggregated summary of the individual-item data. These widely used "data-reduction" procedures identify individual survey items that correlate highly with one another, indicating they may be measuring the same (or a similar) construct. This section contains information on the contents and characteristics of the scales and other variables used in this study.

Although a variety of factor analytic procedures are available, the research group chose to use principal axis analysis. Only items with rotated factor loadings greater than .40 were considered in forming a scale. Because the procedures adopted an Oblimin criterion with Kaiser Normalization rotation, factors may be correlated, and some items may load above .40 on multiple factors. In those instances, items were assigned to a factor based on the magnitude of the loading, the effect of keeping/discarding the item on the scale's internal consistency (alpha) reliability (see below), and on professional judgment. In some instances, items loading above .40 on more than one factor were discarded. Factor scale scores were formed by summing individuals' responses on the component items of a scale and then dividing by the number of items in the scale [24].

The criterion measure of this study is engineering seniors' post-graduate plans for graduate school[a]. To measure plans for graduate school attendance three years after graduation, three sub-scales are employed: 1) will be in graduate school preparing to become an engineering faculty member; 2) will be in graduate school in engineering preparing to work in industry, government, or non-profit organization; and 3) will be in graduate school in a field other than engineering (business, medicine, law, etc.). Independent variables include student background (gender, race/ethnicity, and foreign-born status), SAT math scores as an indicator of mathematics proficiency prior to college, and students' self-rating of engineering skills. Women are a reference group in the gender variable. The race/ethnicity variable contains five categories; African American, Asian American, Hispanic/Latino American, other race/ethnicity group, and White as a reference group. The study also compares the plans of foreign-born and U.S. born students (with the latter as the reference group). Four scales measuring graduates' self-rates of their abilities in engineering knowledge and skills are also employed: fundamental skills, leadership skills, communication skills, and teamwork skills. In this study, fundamental skills are defined as the ability to apply math and science to engineering problems. The internal consistency (alpha) reliabilities for the scales range from .71 to .90. Table 1 provides descriptive statistics on each of these variables

Table 1. *Variables and Descriptive Statistics*

DEPENDENT VARIABLE	**Percent**
After you graduate, how likely: Be in graduate school preparing to become an engineering faculty member	
definitely won't	25.0%
probably won't	42.9%
not sure	22.9%
probably will	7.8%
definitely will	1.4%
After you graduate, how likely: Be in graduate school in engineering preparing to work in industry, government, or non-profit organization	
definitely won't	8.5%
probably won't	19.8%
not sure	43.2%
probably will	23.6%
definitely will	4.9%
After you graduate, how likely: Be in graduate school in a field other than engineering (business, medicine, law, etc.)	
definitely won't	18.1%
probably won't	39.2%
not sure	28.4%
probably will	11.5%
definitely will	2.8%

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[a] The P2P survey asks engineering students if they want to work in or outside of engineering as well as about plans for graduate school enrollment. I focused only on graduate school plans in this study.

Table 1. *Variables and Descriptive Statistics (Continued).*

INDEPENDENT VARIABLE	**Percent**	
Gender		
Man	72.8%	
Woman (reference group)	27.2%	
Race/ Ethnicity (Dummy coded, 1=yes, 0=no)		
African American	2.8%	
Asian American	8.1%	
Hispanic/ Latino American	5.8%	
Other [a]	19.3%	
Caucasian American (reference group)	64.4%	
Foreign-born Status		
Foreign-born students [b]	13.9%	
U.S. born students	86.1%	
	Mean	**Std. Dev.**
SAT Math score	633.42	80.65
Fundamental Skills [c] .(alpha = .71)		
Applying Math & Science to: The physical sciences to engineering problems	3.79	.88
Applying Math & Science to: Math to engineering problems	3.99	.84
Applying Math & Science to: Computer tools and applications to engineering problems	3.53	1.03
Communication Skills [c]. (Alpha = .86)		
Make effective audiovisual presentations.	3.78	.93
Construct tables or graphs to communicate a solution.	4.06	.81
Write a well-organized, coherent report.	3.81	.92
Communicate effectively with people from different cultures or countries.	3.40	1.06
Communicate effectively with clients, teammates, and supervisors.	3.94	.85
Communicate effectively with non-technical audiences.	3.82	.94
Leadership Skills [c] . (Alpha = .90)		
Develop a plan to accomplish a group or organization's goals.	3.83	.90
Help your group or organization work through periods when ideas are too many or too few.	3.65	.95
Take responsibility for group's or organization's performance.	3.92	.92
Motivate people to do the work that needs to be done.	3.60	1.01
Identify team members' strengths/weaknesses and distribute tasks and workload accordingly.	3.76	.99
Monitor the design process to ensure goals are being met.	3.70	.95
Teamwork Skills [c] .(alpha = .86)		
Work in teams of people with a variety of skills and backgrounds.	4.04	.79
Work with others to accomplish group goals.	4.07	.76
Work in teams where knowledge and ideas from multiple engineering fields must be applied.	3.75	1.03
Work in teams that include people from fields outside engineering.	3.58	1.08
Put aside differences within a design team to get the work done.	3.96	.94

[a] The category includes Native American; Middle Eastern American; Multi-race; and other racial/ethnicity.

[b] The category includes Foreign National and Naturalized Citizen, which indicates this measure does not identify U.S. citizenship.

[c] Question stem for items in scale from student survey: “Please rate your ability to apply in a variety of areas:” Responses were given using a five-point scale, where 1 = “Weak/none” and 5 = “Excellent.”

Analytical Procedures

This study examines three outcomes measuring graduate school plans: 1) to become engineering faculty; 2) to prepare for engineering professions; and 3) to attend other graduate schools than in engineering. Because the dependent variables have an ordered (from low to high) scale (1=definitely won't; 2=probably won't; 3=not sure; 4=probably will; and 5=definitely will), either ordinal or multinomial logistic regression methods are recommended[25]. Likelihood-ration t-test of the Parallel Regressions Assumption revealed that the assumption was violated and thus multinomial logistic regression as was the appropriate technique [25]. I therefore chose to use multinomial logistic regression to analyze the model, designating *definitely won't be in graduate school* as the base category.

This study uses odds ratios to facilitate the interpretation of results in a way similar to how one interprets coefficients in Ordinary Least Squares (OLS) linear regression. The odds ratio represents the change in the odds of each category of graduate school plans (*definitely will, probably will, not sure, or probably won't)* relative to the base category (*definitely won't be in graduate school)* that is associated with a one-unit change in a specific independent variable, while holding all other variables constant. An odds ratio greater than one represents an increase in the likelihood of an outcome relative to the reference category, while an odds ratio of less than one represents a decrease in the likelihood[26]. Essentially, odds ratios are the comparison of the probability of one event occurring versus another. Odds ratios can be produced from the logistic regression coefficients by performing the following transformation: $OR=e^{\beta}$. As opposed to OLS regression coefficients, odds ratios are not linearly additive—in order to compare the relative effect of odds ratios greater than one to those less than one, we have to take the inverse of the latter [27].

Limitations

Like all studies, this one has its limitations. Because the P2P survey data are cross-sectional, the study is not able to measure engineering students' actual career choice and enrollment in graduate school upon their graduation. This study assumes that the students' post-graduation plans are proxy measures that predict actual choice of graduate school enrollment; however, students' plans and actual choice may be different. Also, the P2P survey asks engineering students what they plan to do three years after graduation; engineering graduates, however, may decide to switch their field or enroll in graduate study after a period of employment in the field.

An additional limitation is the use of self-reported data for student ability in engineering knowledge and skills. Higher education researchers and administrators have frequently used self-reported gains as indicators of student learning or ability, but the literature in this area is admittedly mixed. Bowman reports that some researchers found strong correlation between subjective and objective assessments, while others reported strong divergence between subjective and objective assessments[28]. Although direct measures of learning, such as a standardized, objective test would be preferable to self-reported abilities, such assessments are time-consuming and costly to collect. Moreover, there is no widely used standardized test of the engineering learning particularly for the learning outcomes employed here[29]. Until such tests are available, self-reports of engineering abilities are a reasonable proxy, but should be interpreted cautiously.

Findings

In this study, the multinomial logistic regression analyses examined if students' demographic background, math proficiency prior to college, and the self-ratings of their engineering skills influence their graduate school plans. A review of the statistically significant odds ratios in Table 2, Table 3, and Table 4 indicates that the odds of planning to enroll in graduate school varies with students' gender and race/ethnicity, math proficiency prior to college, and self-rated abilities in certain engineering skills. Being foreign-born was controlled in the analyses. I will now detail the results of the models used to examine each of the three graduate school plans.

Engineering graduate school plans to become faculty members

In terms of students' sociodemographic background, women students were more likely than men to respond that they *probably will* be in graduate school for academic career purposes, compared to the reference category of *definitely won't* (Table 2). Asian and Hispanic students were more likely to plan to attend graduate school for academic job preparation than White students. On the other hand, African American students are three times less likely than Whites to have graduate school plans.

Seniors' fundamental skills (i.e., skills regarding applying math and science to engineering problems) were positively associated with their graduate school plans to prepare for faculty jobs. Seniors with lower confidence in their fundamental skills were 1.3 to 2.5 times more likely to report that they definitely will not plan to enter graduate school, compared to all other categories. Students who reported higher levels of communication skills were also 2.5 times more likely to respond that they will definitely plan to pursue engineering graduate education for faculty jobs. However, of the seniors who were leaning towards not attending graduate school, those who reported higher leadership skills were more definite about their intentions not to attend.

Table 2[a]. *The likelihood of entering graduate school to prepare for an engineering academic career.*

		B	Std. Error	Wald	Sig.	Odds ratio	Inverse Odds ratio
definitely will	Intercept	-26.138	2.321	126.847	***		
	Communication Skills	.907	.306	8.774	**	2.476	
	Fundamental Skills	.905	.271	11.174	**	2.471	
	Asian American	.790	.352	5.034	*	2.203	
probably will	Intercept	-2.496	1.009	6.120	*		
	Fundamental Skills	.331	.145	5.215	*	1.392	
	Hispanic/Latino American	1.239	.257	23.302	***	3.452	
	Women	.619	.228	7.382	**	1.856	
not sure	Intercept	.309	.715	.187			
	Fundamental Skills	.653	.104	39.788	***	1.921	
	Leadership Skills	-.442	.114	15.122	***	.642	1.556
	SAT math score	-.003	.001	17.201	***	.997	1.004
	African American	-1.081	.371	8.496	**	.339	2.946
	Hispanic American	.642	.217	8.804	**	1.901	
probably won't	Intercept	-.470	.594	.627			
	Fundamental Skills	.265	.087	9.327	**	1.303	
	Leadership Skills	-.331	.097	11.694	*	.718	1.392
	Asian American	-.324	.162	4.010	*	0.724	1.382

[a] Contains only significant results

Engineering graduate school plans to prepare to work in industry, government, or non-profit organization

Students' gender was not related to their graduate school plans (Table 3). With the exception of Hispanic/Latino students, who were 2.2 times more likely than Whites to report they probably will be in graduate school three years after graduation, there were no differences by race/ethnicity in graduate school plans.

Students' SAT math score was negatively associated with the odds of graduate school plans. Since a one point change in SAT math score is of little practical use, I instead calculated the odds ratios based on a one standard deviation (81 point) change. Overall, students with a higher SAT score are approximately 1.6 times more likely to say they definitely will not plan to attend grad school than those with an average score. On the other hand, students' fundamental skills were positively associated with their engineering graduate school plans. Overall, students who reported lower fundamental skills were 1.7 to 3.8 times more likely to say that they definitely will not pursue engineering graduate school, compared to all other categories.

Although teamwork skills also had a positive relationship with graduate school plans, the effect of those skills (the odds ratios) were approximately half of the fundamental skills. Therefore, seniors' fundamental skills play a more critical role in encouraging their graduate school plans. Seniors with higher leadership skills, however, were much less likely to plan to attend graduate school to prepare for an engineering career. Students who rated higher leadership skills were 1.5 to 2.2 times more likely to report that they definitely will not enter engineering graduate school across all other categories. Leadership skills are negatively associated with graduate school plans regardless of whether students are preparing for academic or professional positions (Tables 2 and 3).

Table 3[a]. *The likelihood of entering graduate school to work in industry, government, or non-profit organization*

		b	Std. Error	Wald	Sig.	Odds ratio	Inverse Odds ratio
definitely will	Intercept	-.518	1.244	.174			
	Teamwork Skills	.455	.199	5.208	*	1.576	
	Fundamental Skills	1.329	.186	51.028	***	3.779	
	Leadership Skills	-.797	.197	16.424	***	.451	2.219
	SAT math score	-.006	.002	15.488	***	.994	1.006
probably will	Intercept	3.072	.901	11.623	**		
	Teamwork Skills	.320	.143	5.009	*	1.377	
	Fundamental Skills	1.043	.132	62.292	***	2.837	
	Leadership Skills	-.720	.145	24.677	***	.487	2.054
	SAT math score	-.006	.001	24.716	***	.994	1.006
	Hispanic American	.809	.311	6.778	**	2.246	
not sure	Intercept	1.266	.858	2.178			
	Teamwork Skills	.328	.132	6.146	*	1.388	
	Fundamental Skills	.698	.121	33.413	***	2.011	
	Leadership Skills	-.417	.134	9.613	**	.659	1.517
	SAT math score	-.003	.001	6.656	*	.997	1.003
	Hispanic American	-.626	.296	4.460	*	.535	1.870
probably won't	Intercept	1.740	.932	3.484			
	Fundamental Skills	.501	.132	14.407	***	1.651	
	Leadership Skills	-.485	.147	10.889	**	.616	1.625
	SAT math score	-.004	.001	12.247	***	.996	1.004

[a] Contains only significant results

Graduate school plans in a field other than engineering (business, medicine, and law)

Women seniors were 1.7 times more likely to say that they will probably plan to attend graduate school outside engineering than men (Table 4). Hispanic students were 1.8 to 2.3 times more likely than Whites to plan to pursue graduate education outside the field. African-American students were more than 4.6 times more likely than Whites to be unsure about their graduate school plans (compared to the reference category of *definitely won't*).

Math proficiency and fundamental skills did not influence seniors' plans to attend graduate school outside engineering. Higher leadership skills were negatively related to the odds of making non-engineering graduate school plans, but seniors' teamwork and communication skills were positively related. Overall, communication skills positively influenced non-engineering graduate school plans almost twice as much as teamwork skills.

Table 5[a]. *The likelihood of graduate school in a field other than engineering*

		B	Std. Error	Wald	Sig.	Odds ratio	Inverse Odds ratio
definitely will	Intercept	-7.873	1.672	22.177	.000		
	Communication	.871	.233	14.023	.000	2.390	
	Leadership	-.418	.208	4.034	.045	.659	1.518
probably will	Intercept	1.474	.816	3.259	.071		
	Teamwork Skills	.287	.138	4.329	.037	1.332	
	Fundamental Skills	-.295	.122	5.891	.015	.744	1.343
	SAT math score	-.002	.001	5.815	.016	.998	1.002
	Hispanic American	.809	.259	9.723	.002	2.245	
	Women	.505	.215	5.488	.019	1.656	
not sure	Intercept	.432	.740	.341	.559		
	African American	1.521	.357	18.155	.000	4.575	
	Hispanic American	.600	.229	6.845	.009	1.822	
	Women	.621	.185	11.286	.001	1.860	
probably won't	Intercept	1.132	.655	2.990	.084		
	Teamwork Skills	.278	.105	7.017	.008	1.321	
	Leadership Skills	-.393	.105	13.921	.000	.675	1.482
	African American	.769	.253	9.220	.002	2.157	
	Hispanic American	.575	.218	6.945	.008	1.778	

[a] Contains only significant results

Conclusion

The question of graduate school plan is a critical one for the field of engineering as both industry and higher education institutions seek to understand how to increase the production of highly-skilled individuals. Engineers and scientists have helped the nation meet national workforce needs, maintained or improve quality of life, and remained economically competitive in an increasingly global workplace. In this paper I explored the viability of three proposed explanations for graduate school attendance in STEM fields.

I explored if there are gender or race/ethnicity differences in planning for graduate school. The findings suggest that women and underrepresented minority students are more likely to plan to attend graduate school for academic careers than their counterparts. Although women and URM students continue to be underrepresented in engineering graduate school[1], at least, they make a plan for graduate school enrollment during their senior year. This finding suggests a role for engineering educators in encouraging women and URM seniors to follow up their plans by enrolling in engineering graduate school. Since this research did not control for senior's socio-economic status (SES), there is a need for further research examining if students' SES moderates the relationship between race/ethnicity and graduate school plans.

Women and URM seniors also plan for non-engineering graduate school more than their counterparts. They may consider this option assuming that graduate programs outside engineering might have warmer climate than those in engineering[30]. This findings, however, should not be interpreted as suggesting that women and URM leave engineering fields after finishing graduate school (for example, in business) since they might return to the engineering profession after their graduate school.

While research suggests that students who are proficient in mathematics at an early age choose engineering programs[5], this study suggests that higher math proficiency is negatively associated with graduate school plans. It is possible that students who have a high SAT math score might be able to easily obtain an engineering job immediately after graduation and may then pursue graduate school after spending some time in the workforce.

These findings appear generally consistent with theories of vocational choice which posit that individuals gravitate toward careers consistent with their vocational aspirations, interests, competencies, and self-perceptions[18]. Engineering graduates who are most confident in their fundamental skills are more likely to pursue engineering graduate school to prepare for either faculty jobs or industry. Seniors may recognize that these abilities will help them to be successful in engineering graduate school. The effect size of fundamental skills is higher than that of mathematics proficiency and professional skills in predicting engineering graduate school plans. This interpretation is supported by the finding that seniors' confidence levels in their engineering fundamental skills do not influence graduate school plans outside of engineering.

Professional skills are also related to engineering graduate school plans. However, the patterns are different depending on the kind of skill. Leadership skills are negatively associated with both engineering and non-engineering graduate school plans. Given that the leadership skills scale used for this research refers to students' organizational and managerial abilities, seniors may view these skills as more appropriate to work in the engineering profession rather than to graduate school attendance. Therefore, students with greater confidence in leadership skills might choose engineering career without further education. This set of findings is also consistent with the recent finding by Sheppard et al. that engineering students with greater self confidence in their professional and interpersonal skills were less likely to plan to attend graduate school in engineering (or to work in engineering)[6]. While Sheppard et al. addressed professional and interpersonal skills as one scale[6], however, I explored the impact of three different types of professional skills (communication, leadership, and teamwork) on graduate school plans.

This study suggests that teamwork and communication skills are positively related to both engineering and non-engineering graduate school. The teamwork skills scale that I used includes items, such as not only work in team but also work with people from different backgrounds and integrate ideas from multiple engineering fields in team. The communication skill scale contains items, such as verbal and written communication skills but also effective communication with clients, teammates, supervisors, and non-technical audiences. These skills are currently emphasized by engineers in both academia and the profession; thus, engineering students with the greater confidence of teamwork and communication skills might pursue graduate study inside (or outside) engineering.

One important question this study cannot answer is how graduate study in fields outside engineering may complement undergraduate study in the field and advance one's career in engineering. Pursuing a graduate program outside engineering is not necessarily a signal of an individual's intention to leave the field. Indeed, many engineers pursue graduate studies in business to further their careers in settings where management skills are critical to career advancement in technically oriented industries. Similarly, individuals may pair an undergraduate degree in engineering with graduate study in medicine or science to prepare for work in biomedical engineering. Much additional research is needed to understand when and why engineering students pursue advanced education in the field if the engineering community is to improve domestic production of human resources and help individuals attain their educational and career goals. It is also important to note that because this paper reports on graduate school attendance plans three years after the attainment of the undergraduate degree, it is likely to underestimate the numbers of engineering students who eventually pursue graduate study in the field.

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