have magnified the perception that there has been a lack of similarly qualified domestic students in STEM graduate programs.The United States cannot continue to rely on compensatory overseas talent (Bowen, Chingos, & McPherson, 2009): between fall 2011 and fall 2012, the rates of foreign enrollments in graduate programs in science and engineering have increased by just 3% (National Science Board, 2014).

It is important to note that patterns in graduate school attendance may vary across STEM disciplines. Specifically, engineering students might be less likely to pursue graduate study than students in mathematics, chemistry, or physics. Engineering majors and careers have attracted many working-class and first-generation students, who are particularly likely to view their undergraduate education as a means for upward mobility, but disinclined to consider entering graduate programs (Davies & Guppy, 1997). Women and underrepresented racial minority students are also reluctant to pursue graduate education in engineering, often due to a lack of mentoring, role models, or a chilly climate (Baker, Tancred, & Whitesides, 2002; Museus, Palmer, Davis, & Maramba, 2011).

Researchers have not yet considered the potential impact of engineering students' college experiences – particularly co-curricular participation and self-assessments of their skill sets – on their graduate education choices inside and outside of STEM fields. Furthermore, while a substantial amount of research on graduate school attendance has focused on doctoral graduates, to date there has been limited research on graduate school attendance that includes master's program attendance in relation to other early career alternatives. Such research can inform interventions that promote advanced study in engineering, especially given the applied nature of the field and the fact that growth in science and engineering degrees is higher at the master's level (57%) than at the bachelor's (39%) or doctoral levels (38%; National Science Board, 2014).

Thus, we examined key factors that contribute to engineers' decisions regarding graduate study soon after completion of an engineering bachelor's degree. We use the term *engineer* for someone who has earned an undergraduate engineering degree in the United States. More specifically, we explored the influence of engineers' mathematics proficiency prior to college, their self-assessments of their skills during college, and their college experiences on graduate school attendance in engineering or in other fields within three years after receiving a bachelor's degree.

Graduate School Attendance in STEM

Previous research suggested three explanations of how students in STEM fields choose to pursue, persist, and complete STEM graduate degrees: math proficiency, match between qualifications and interests, and demand factors (Lowell, Salzman, Bernstein, & Henderson, 2009).

Math proficiency The first explanatory perspective suggests that if students are proficient in mathematics and science at an early age, this proficiency encourages them to choose STEM undergraduate and graduate schools as well as STEM employment (Seymour & Hewitt, 1997). Students who take trigonometry, precalculus, or calculus in high school are more likely to attain STEM degrees than their peers (Chen & Weko, 2009). In contrast, high school students who only take lower levels of math or science are not able to choose a major in engineering or an engineering career due to admissions or degree requirements (Bozick & Ingels, 2007). Furthermore, although students with above-average math proficiency are more likely to attend STEM graduate programs, research indicated that this proficiency does not tend to influence students' persistence in graduate school and doctoral degree completion (Bair & Haworth, 2005; Herzig, 2004).

Math proficiency is highly relevant to underrepresented racial minority (URM) and women students' access to STEM fields. Most research addressing the low enrollment of URM students identified academic preparedness in mathematics as one of the most salient factors influencing their choice of graduate school in engineering (Anderson & Kim, 2006; Dix, 1987). Adelman (1998) argued that high-achieving women engineering students are especially likely to switch fields to avoid competition with male students. For both URM and women students, stereotype threat and unwelcoming climates may lead them to believe that they can be more successful in fields where they are not traditionally regarded as a minority group (Adelman, 1998; Steele, James, & Barnett, 2002).

Match between qualifications and interests The second perspective suggests that students choose STEM graduate education on the basis not only of their qualifications but also their interests, self-efficacy, self-confidence, and self-esteem in relation to specific disciplines. In his social cognitive learning theory, Bandura (1986) defined self-efficacy as an individual's judgments of their abilities to accomplish specific tasks or objectives, and argued that self-efficacy mediates between actual ability and career choice. Using self-efficacy theory, both Wang and Staver (2001) and Mau (2003) found that career aspirations and interest in engineering disciplines during college influence persistence in engineering professions. A student may have high ability in mathematics and science, but without self-efficacy their career or graduate school choice may exclude engineering fields. Thus, the low number of women and underrepresented minority students in engineering graduate programs might be related to self-doubt or loss of self-esteem during their undergraduate education (Anderson, 1994; Marra, Rodgers, Shen, & Bogue, 2009).

Although researchers investigated the relationships between self-efficacy and graduate school choice, self-assessed abilities or skills received less attention. Some researchers treated reports of self-efficacy as equivalent to self-estimated or self-rated abilities, given that both involve a person's beliefs about their personal capabilities (Tracey & Hopkins, 2001). In contrast, other researchers distinguished self-rated abilities in certain knowledge and skill areas from self-efficacy (Brown et al., 2000; Bong & Skaalvik, 2003). In the development of vocational interests and choices, self-rated abilities were defined as normative judgments about one's current work-related abilities (Swanson, 1993). Some researchers measured self-rated abilities by asking respondents to compare themselves to others of their own age on artistic ability, scientific ability, and so forth, using a scale from "low ability" to "high ability" (Brown et al., 2000; Swanson, 1993). On the other hand, self-efficacy has been defined as a reflection of an individual's expectations about future performance in specific tasks and environments that are based on judgments of capabilities (Lent & Brown, 2006; Lent, Brown, & Hackett, 1994). Marra et al. (2009) measured female engineering students' self-efficacy using questionnaire items such as "I can succeed in engineering curriculum." Brown et al. (2000) summarized this distinction, explaining that self-efficacy focuses on prospective or future-oriented performance capabilities, whereas self-rated ability focuses on judgments about current abilities.

Demand factors The third perspective looks to demand or market forces, arguing that labor markets attract students to career paths that will best compensate them for their abilities (Lowell & Salzman, 2007; Lowell et al., 2009). Lowell et al. (2009) argued that high-performing undergraduate students frequently choose not to continue their doctoral education in STEM because of the high starting salaries available to them with a bachelor's degree. Teitelbaum (2001) noted that doctoral studies require a long period of training, yet provide few employment opportunities in research and little increased earning potential. Also, market incentives tend to be more influential in the graduate school decisions of those students whose parents have lower levels of income and education, and cultural and social capital (Perna, 2004). Given the connection between race and socioeconomic status in the United States, URM students might be particularly sensitive to market incentives. Pearson (1987) suggested that certain minority groups tend to choose immediate employment after college graduation rather than advanced study given the prospects of further financial difficulties, the academic risk of graduate study, and labor market uncertainties (Pearson & Fechter, 1994).

In sum, scholars have suggested that rigorous academic preparedness in mathematics and science, good match between qualifications and interests, and market incentives encourage students to continue their graduate education in engineering programs. Yet, while these explanations may help demonstrate the choice of graduate fields, researchers have not yet considered the potential influences on the graduate education choices of STEM students' self-assessment of their skills and educational experiences.

Self-Assessment of Skills

Although previous studies examined the relationship between self-efficacy and engineering students' graduate school enrollment, little research has explored how students' self-assessments of their engineering skills contribute to their choice of engineering in graduate school. Holland (1997) theorized that individuals choose occupations that are consistent with their vocational aspirations, interests, competencies, and self-rated abilities. Exploring the relationships among interests, competencies, and self-rated abilities, Holland (1997) found positive correlations between students' interests in scientific occupations and their scientific competencies. However, the causal relation between competencies and interests in occupations is unclear.

Astin and Astin (1992) examined factors that influenced first-year college students' interests in studying science and in pursuing science-related careers and graduate school. Their research indicated that the most powerful predictor of students' interest in science majors and careers was their entering level of mathematical or academic competency. Similarly, Sax (1994) 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. In an experiment with undergraduate students, Correll (2004) found that students who reported higher assessments of their own mathematical ability were more likely to pursue engineering and science careers than other students.

In addition to self-assessment of mathematical ability, self-evaluation of other desired engineering skills might influence students' persistence in engineering graduate school and related careers. In response to industry demands and changes in professional program accreditation standards, engineering instructors and faculty members are redesigning engineering education to emphasize not only mathematical, scientific, and technical knowledge, but also professional skills and contextual consideration in engineering practice (ABET, 2009; National Academy of Engineering, 2004, 2005). Sheppard et al. (2010) asked engineering seniors to rate their abilities and knowledge compared with their classmates, and found that senior students with greater confidence in their professional and interpersonal skills were less likely to pursue engineering careers or engineering in graduate school. This intriguing finding suggests that students with more confidence in what are sometimes called "soft" skills gravitate toward careers in industry. This research, however, had two key limitations: the research design did not take into account students' confidence in other important engineering skills that the engineering community has emphasized, and the study measured seniors' postgraduate plans rather than their subsequent career or study choices.

Co-curricular Experiences

Higher education researchers have long emphasized the role of co-curricular engagement in graduate school attendance and graduation (Pascarella & Terenzini, 2005). Research on learning and motivation has suggested that situational interests, such as those created by student participation in certain co-curricular activities, may become intrinsic interests over time (Hidi, 1990; Renniger, 2000). Co-curricular engagement might influence students' interests and confidence in particular areas and thus their choices regarding graduate study and careers.

Of co-curricular activities, studies have suggested that involving students in undergraduate research promotes their subsequent pursuit of advanced study in STEM fields (Kremer & Bringle, 1990; Lopatto, 2004; Strayhorn, 2010). Because undergraduate research experiences promote research knowledge and skills (Lopatto, 2007; Seymour, Hunter, Laursen, & DeAntoni, 2004), research self-efficacy (Adekokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013), satisfaction with engineering (Bauer & Bennett, 2003; Seymour et al., 2004), and networking and interaction with faculty members (Astin & Astin, 1992; Kardash, 2000), policy makers and educators believe that these experiences help students prepare for graduate education (Boylan, 2009).

Other co-curricular activities might encourage engineering students' graduate school choice by increasing their interests and promoting interactions with peers and faculty (Gellin, 2003; Pascarella & Terenzini, 2005). Thiry, Laursen, and Hunter (2011) found that at four highly selective liberal arts colleges, internships and clinical programs allowed students to engage with a real-world project, helping them to clarify future career goals and develop their professional identities. Students' service learning and community service experiences also contribute to their improved social engagement, problem solving, and professional skills (Shuman, Besterfield-Sacre, & McGourty, 2005; Smith, Sheppard, Johnson, & Johnson, 2005; Tempest, Dika, Pando, & Lopez, 2012). Since co-curricular experiences may also influence decisions regarding graduate education (Anakwe & Greenhaus, 2000), researchers should examine the influences of co-curricular participation on graduate education attendance.

Using theory and research regarding mathematics proficiency, match between qualifications and interests, and the effect of college experiences, we explored the research question, How are engineers' decisions to pursue graduate study influenced by their mathematics proficiency prior to college, their self-assessments of their engineering abilities during college, and their co-curricular activities during college?

Method

Design, Population, and Sample

We used data from a nationally representative dataset developed for the National Science Foundation-sponsored research project, Prototype to Production: Conditions and Processes for Educating the Engineer of 2020 (NSF DUE-0618712). The Prototype to Production study investigated the effects of curricular, instructional, and organizational practices on student learning. Data were collected from 30 four-year colleges and universities that are representative of all four-year U.S. engineering schools offering two or more ABET-accredited programs in the seven engineering disciplines: bioengineering and biomedical, chemical, civil, electrical, general, industrial, and mechanical. In the aggregate, these programs accounted for 70% of all baccalaureate engineering degrees awarded in 2007. The stratified sample design of institutions was also representative according to highest level degree offered (bachelor's, master's, or doctorate) and type of institutional control (public or private).

The engineer population was individuals who earned a bachelor's degree during the academic year 2005–2006 in one of the seven engineering disciplines at the sampled institutions. All engineers meeting the study's population specifications were invited to participate. Chi-square goodness-of-fit tests indicated that engineers at the participating institutions were marginally unrepresentative of the overall population of engineers: population-sample differences ranged from one to 13 percentage points (Table 1). Consequently, individual weights were created to adjust for any campus-specific response bias due to respondents' sex, race/ethnicity, and engineering discipline, as well as for differing response rates across institutions. An overall weight was calculated by multiplying these individual weights and applied to all respondents to produce a sample that can be considered representative of the population of engineers as specified, both on each campus and nationally.

Invitations to participate were sent to 7,307 engineers during the spring and summer terms of 2009, of whom 1,403 responded (19%). Conversations with colleagues around the country indicated that such a response rate is not uncommon in multi-institutional studies. Survey response rates, moreover, have been in decline for several decades (Baruch 1999; Dey 1997;

Table 1 Descriptive Statistics of Survey Respondents

Engineer[a] characteristics	288-institution population (N = 50,201) (%)	30-institution sample (n = 8,294) (%)	Respondents (weighted[a] and imputed) (n = 1,420) (%)
Engineering discipline			
Bioengineering and biomedical	5.7	5.6	6.3
Chemical	8.5	12.2	9.1
Civil	17.1	16.5	14.8
Electrical	28.0	22.6	32.1
Industrial	7.2	7.4	8.1
Mechanical	31.2	31.1	24.3
General	2.3	2.5	5.3
Gender			
Male	79.9	73.7	79.3
Female	20.1	26.3	20.7
Race/Ethnicity			
African American	4.7	2.9	5.3
Asian or Pacific Islander	12.7	6.9	15.6
Hispanic	6.7	4.3	7.4
Native American Indian/Alaskan	0.5	0.1	0.1
Other	7.1	8.6	3.8
Foreign	6.9	2.4	6.6
Caucasian	61.3	74.7	61.2

Source. American Society of Engineering Education.
Note. Responses in each category total 100%.
[a]Engineers are individuals who have earned an undergraduate engineering degree in the United States. [b]Weighted by gender, race/ethnicity, discipline, and adjusted for institutional response rate.

Smith 1995), and web-based surveys often have relatively low response rates (Porter & Umbach, 2006; Van Horn, Green, & Martinussen, 2009). Still, the low response rate, despite corrective weighting, may pose nontrivial threats to the external validity of the study's findings. A series of chi-square goodness-of-fit tests in terms of sex, race/ethnicity, and disciplines determined the representativeness of the sample for the populations that received the survey at each institution. However, more extensive analyses could not be conducted to determine representativeness because institutions provided only data related to these variables for their engineers.

Missing data were imputed following procedures recommended by Dempster, Laird, and Rubin (1977) and by Graham (2009), using the expectation-maximization (EM) algorithm of the Statistical Package for the Social Sciences (SPSS) software (v.18). Although the EM algorithm is perhaps the most commonly used in educational literature (Cox, McIntosh, Reason, & Terenzini, 2014), EM can yield standard errors that are artificially small, threatening the validity of subsequent hypothesis testing (Graham, 2009; von Hippel, 2009). It is important then to bear in mind the possibility of Type I errors, even despite our adopting critical *p*-values of .05 (Cox et al., 2014).

Given that this study was focused on domestic engineers, we did not examine data from 71 foreign nationals. Foreign national student groups tend to be heterogeneous, and more detailed data were not available to demonstrate the groups' characteristics, such as when they moved to the Unites States, whether they attended high schools in the Unites States, or their race/ethnicity along with their citizenship. We also did not include 104 respondents who had enrolled in both engineering and nonengineering graduate degrees since the interpretation for their career path is not clear. We included this limitation in the Discussion section as motivation for future research. After these restrictions, our final sample had 1,119 engineers. Of these, 455 were either enrolled in or had completed an engineering graduate program, 156 had enrolled in or had completed a graduate program outside engineering, and 508 were working in engineering and had not yet enrolled in any form of graduate education.

Measures

Instrument development A team of education and engineering researchers (two faculty members in education, two faculty members in engineering, two postdoctoral researchers, and seven graduate research assistants) collaborated on the development of the instrument. The team began with an extensive literature review on topics related to key learning outcomes identified by the National Academy of Engineering's (2004) *Engineer of 2020* report. In addition to providing conceptual guidance for survey development, findings from this literature review generated a bank of potential survey items related to engineering students' college experiences and learning outcomes. In cases where available scales had acceptable psychometric properties, items were adopted or minimally revised. The team also conducted interviews and focus groups with engineering administrators, faculty members, students, and alumni at five campuses (three four-year institutions and two community colleges) to develop new survey items and ensure appropriate coverage of key topics. Engineering faculty and administrators reviewed drafts of potential survey items to evaluate and refine the survey, and the instrument was pilot tested with 482 students at the four-year institutions for newly developed items. The research team used factor analysis techniques to explore pilot results and further revised survey items according to these findings. The team again met with focus groups of engineering faculty members and administrators from Pennsylvania State University to review the revised student survey and assess its construct validity (i.e., whether the items represent their intended purpose) before administering the final version. To provide a more compact, aggregated summary of the individual items, the team used factor analysis and selected the principal axis factoring method (oblimin with Kaiser normalization rotation). This statistical procedure determined the degree of correlation between items, and highly correlated items were combined to form scales. Items were assigned to scales on the basis of the magnitude of loading from the principal axis analysis method, the effect of keeping or discarding the item on the scale's internal consistency reliability, and professional judgment. As recommended by Armor (1974), scales were computed by summing respondents' scores on component items and dividing the sum by the number of items in the scale.

Variables Attendance in engineering graduate programs was the criterion measure. Engineers reported on their current enrollment in engineering graduate programs as well as graduate degree completions; both groups were included in our measure. The degree programs varied between the master's and doctoral levels; because we were interested in graduate education generally, we combined master's and doctoral degree enrollments and degrees in our analysis. The dependent variable thus had three categories: currently enrolled in or received a graduate degree in engineering, enrolled in or received a degree in a nonengineering graduate program, and working and not currently or formerly enrolled in any graduate program.

The analytical variables in this study fell into two groups: control (covariates) and independent variables. In order to remove potentially confounding effects related to the characteristics of the institutions that were home to the engineering disciplines and engineering graduates under study, controls were made for institutional size and highest degree awarded by institutions. We categorized institutional size as small, medium, or large using the intervals developed for the 2005 Carnegie Classification. "Small" was defined as an undergraduate enrollment of 1,000–3,000; "medium" as 3,000–10,000; and "large" as more than 10,000. To reflect institutional mission, we used the Integrated Postsecondary Education Data System data to identify three levels of highest degree offered: bachelor's, master's, and doctoral. We created a variable with five categories of academic majors: electrical engineering (reference group), mechanical engineering, civil engineering, chemical engineering, and others (bioengineering and biomedical, general engineering, and industrial engineering). Several precollege characteristics were also controlled for: sex, race/ethnicity, parental educational level, high school grade point average (GPA) on a 4.0 scale, college GPA and SAT verbal score on a 200 to 800 scale.

Three sets of independent variables were used: proficiency in mathematics (SAT math score), co-curricular participation, and self-assessments of skills during each engineer's undergraduate years. Co-curricular experiences consisted of five single-item measures: the number of months students reported spending on undergraduate research, months spent on engineering internships, months spent on cooperative educational experiences, months spent on nonengineering community volunteer work, and the extent of engineers' involvement in an engineering club or student chapter of a professional society during their undergraduate experience.

Engineers also reported the level of self-assessments of skills based on their recollections of their senior year. Six measures were used: design skills, contextual competence, interdisciplinary skills, teamwork skills, communication skills, and leadership skills. Design skills (12-item scale, Cronbach's alpha = .86) included the solving of ill-structured problems, creative approaches, nontechnical considerations, and critical skills as identified in the engineering accreditation criteria (ABET, 2009). Contextual competence (four-item scale, Cronbach's alpha = .90) assessed the ability to solve engineering problems in real-world contexts (ABET, 2009). Interdisciplinary skills (eight-item scale, Cronbach's alpha = .86) assessed the ability to work across engineering and nonengineering fields (NAE, 2004). Teamwork skills included self-assessments of working in teams of people who have different skills and backgrounds as well as people from fields outside of engineering (five-item scale, Cronbach's alpha = .86).

Communication skills measured engineers' self-assessments of not only oral and written communication, but also effective communication with people from different cultures or countries, and from outside engineering (six-item scale, Cronbach's alpha = .87). Leadership skills assessed engineers' ability to develop plans, take responsibility, and monitor process to ensure goals are being met (six-item scale, Cronbach's alpha = .90). With the exception of contextual competence and interdisciplinary skills, all other scales have psychometric properties that have been established in the literature and have been used in prior studies of undergraduate engineering (Strauss & Terenzini, 2005; Lattuca, Terenzini, & Volkwein, 2006). The additional validity tests of the contextual competence scale were established by Ro, Merson, Lattuca, and Terenzini (2015), and validity of the interdisciplinary skills scale was established by Lattuca, Knight, and Bergom (2013). Tables 2 and 3 provide descriptive statistics of independent, dependent, and control variables and the Appendix provides operational information on all content of the variables.

Analytical Procedures

Using a hierarchical multinomial logistic model (HMLM), we examined the unique contributions of students' math proficiency prior to college, college experiences, and self-assessment of abilities during college years to graduate school attendance. Although a multilevel analysis was not the primary research interest of this study, the HMLM method had important benefits. Using a multinomial logistic regression model would have misestimated standard errors by not taking into account the correlations between individuals within the same institutions. Thus, standard logistic regression violates the assumption of complete independence of observations and would lead to biased estimates of standard errors. In contrast, the HMLM method enables us to adjust for clustering within institutions.

Table 2 Descriptive Statistics of Variables

	%
Dependent variable	
Currently enrolled in or received degree in engineering graduate school	38
Currently enrolled in or received degree nonengineering graduate school	20
Working without any graduate study	42
Control variables	
Female	26
Racial/ethnic minority	24
Mother and/or father has at least a bachelor's degree	75
High school GPA at least 3.5	78
Engineering program GPA at least 3.5	39
Engineering discipline	
Civil	15
Chemical	9
Electrical	32
Mechanical	24
Others (Bioengineering and biomedical, industrial, general)	20
Large institution	10
Doctorate-degree awarding institution	44

Table 3 Descriptive Statistics of Independent Variables

	M	*SD*	Min	Max
Proficiency in mathematics				
SAT score	679.8	76.39	222	800
Co-curricular participation				
Undergraduate research	6.5	8.2	0	36
Engineering internships	5.4	6.7	0	36
Cooperative educational experiences	2.2	5.0	0	36
Nonengineering community volunteer work	9.1	12.1	0	36
Engineering club or student chapter of a professional society	2.3	1.3	1	5
Abilities and skills				
Design skills	3.2	0.7	1	5
Contextual awareness	2.8	0.9	1	5
Interdisciplinary skills	3.5	0.7	1	5
Teamwork skills	3.5	0.8	1	5
Communication skills	3.6	0.7	1	5
Leadership skills	3.2	0.8	1	5
Control variable				
SAT verbal score	603.1	91.1	222	800

We used a Bernoulli model because our dependent variable ($y = 1, 2, 3$) was nonordered and categorical, where the respective values of y referred to currently enrolled in or received degree in engineering graduate school, currently enrolled in or received degree outside of engineering graduate school, and working without any graduate study. Level 1 was the individual level; in our HMLM analysis, this outcome functioned as a dependent variable predicted by institutional characteristics at Level 2. The institution-level variables, however, were treated as covariates (control variables) rather than as predictors in this study.

This study used odds ratios to facilitate the interpretation of results. Odds ratios are the comparison of the probability of one event occurring versus another. Using $y = 3$ as the baseline outcome, in the Results section we report the impact of control and independent variables in predicting first outcome $y = 1$ in relation to $y = 3$ and then $y = 2$ in relation to $y = 3$ by presenting each variable's coefficient and corresponding odds ratio. In each case, the odds ratio represented the change in the odds of the given outcome relative to $y = 3$ that is associated with a one-unit change in a specific independent variable while holding all other variables constant. An odds ratio greater than 1 represented an increase in the likelihood of attending engineering graduate school relative to not enrolling. An odds ratio of less than 1 represented a decrease in the likelihood of engineering graduate school attendance. In each model, the coefficients (β) are the natural logs of their respective odds ratios; hence, odds ratios (ORs) can be produced from coefficients by performing the transformation: $OR = e^{\beta}$ (i.e. by taking Euler's number to the power of the coefficient). Odds ratios are not linearly additive. In order to compare the relative effect of odds ratios greater than 1 to those less than 1, we took the inverse of the latter (DesJardins, 2001).

Limitations

Like all studies, this one has its limitations. First, the data were cross-sectional rather than longitudinal. Engineers had to rely on their recollections of their engagement in co-curricular activities and the self-assessment of their skills when they were in undergraduate programs. The self-ratings were likely to be at least partially influenced by respondents' current work status. The survey, though, asked respondents for their abilities during both their senior and current years, thus explicitly asking for distinct appraisals for the two time points. However, we admit the limitation that their senior-year abilities could be relative to their current ones.

Second, there are limitations due to the survey that was used. We had just a single measure of students' math proficiency (SAT score) prior to college. As with almost any single assessment, SAT scores cannot provide a complete measure of math ability, and there are concerns that it is biased against students from lower socioeconomic status and minority backgrounds (Dixon-Román, Everson, & McArdle, 2013; Freedle, 2003; Guinier & Torres, 2002). Our reliance on students' aggregate score on a single assessment curtails our ability to conduct more nuanced analyses of which specific subareas of math proficiency prior to college might be especially important to students' subsequent pathways into graduate study.

Third, although the survey was large and comprehensive, it did not collect respondents' financial information, such as engineers' parental financial support for their education, socioeconomic status (the data has educational level, but not income level), funding opportunities, and employer contributions for education, all of which were likely to influence their decision making for graduate education. Furthermore, one of the outcome-measure categories, graduate school choice for other programs, was not divided into subcategories such as business school, law school, or medical school. Engineers who chose business school and medical school probably had distinctive reasons and motivations for pursuing these advanced degrees. The survey also did not ask whether the engineers were currently enrolled or had ever enrolled part-time (that is, generally taking one course per semester). Hence, this study could not catch all possibilities of the different patterns of enrollment at graduate schools.

Fourth, this study examined graduate school attendance and workforce patterns of engineers during their first three years after college. Engineers may decide to enroll in graduate study after a longer period of employment in the field. Engineers wishing to pursue a full-time MBA degree generally need to have four or more years of full-time work experience before admission; this group would have been missed in this study. Hence, the consequences of academic disciplines and experiences might differ depending on when engineers decide to pursue graduate education.

Finally, we were not able to examine the demand or market forces, which have been advanced as one determinant of the career paths of college graduates. As a result, one immediate cause for concern was our failure to account for outside influences, such as the effects of changes in the engineering industry or economic downturns, on graduate school attendance. Our conceptual framework was necessarily a simplification of reality; however, our analysis was able to explore the usefulness of this framework as it related to the influence of colleges on engineers' graduate school attendance.

Findings

Tables 4 and 5 present findings from the HMLM analysis. Table 4 gives coefficients (β) and corresponding odds ratios for the independent variables when comparing currently enrolled in or receiving a degree in engineering graduate school to working without any graduate study. The coefficients, and corresponding odds ratios, in Table 5 compare enrolled in or receiving degree in a graduate program outside engineering to working without any graduate study. Both sets of results came from a single multinomial model, which controlled for individual demographic and institutional characteristics already mentioned.

Table 4 Engineering Graduate School Attendance

Independent variables	β	*SE*	Odds ratio	Inverse odds ratio
Math proficiency				
SAT math score	0.006	0.002***	1.006	
Co-curricular participation				
Undergraduate research	0.043	0.013***	1.044	
Engineering internships	−0.014	0.017		
Cooperative educational experiences	00.029	0.024		
Nonengineering community volunteer work	0.013	0.010		
Engineering club or student chapter of a professional society	0.093	0.101		
Abilities and skills				
Design skills	−0.238	0.326		
Contextual awareness	−0.240	0.138		
Interdisciplinary skills	0.168	0.185		
Teamwork skills	−0.484	0.140***	0.616	1.384
Communication skills	−0.045	0.164		
Leadership skills	0.503	0.221*	1.654	

Notes: The reference category is no graduate study. Analytical model includes controls for institution and individual engineer's demographics. Odds ratios and inverse odds ratios are provided only for significant estimators.
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Regarding Table 4, SAT math score was a significant positive predictor of enrollment in engineering graduate programs, even after we controlled SAT verbal score and academic GPA. The odds ratio for the SAT math variable was 1.006, which was based on the change associated with just a one-point increase in SAT math score. By extension, a 100-point increase in SAT math score was associated with an odds ratio of 1.6 (a 60% increase in the likelihood of attending engineering graduate school). This was a plausible scale of increase given the standard deviation in SAT math score in our sample was 76.39 (see Table 3).

Of the co-curricular activities, only undergraduate research was a significant predictor; the relationship was positive, with each additional month of undergraduate research increasing the likelihood of enrollment in engineering graduate study by 4%. Of the abilities and skills variables, teamwork skills and leadership skills were both significant. Whereas teamwork skills had a negative effect on the outcome, leadership skills had a positive one. On average, a one-unit increase in students' self-assessments of their teamwork skills on a five-point scale led to a 38% drop (inverse odds ratio of 1.384) in the likelihood of enrolling in engineering graduate study, whereas a one-unit increase in leadership skills led to a 65% increase (odds ratio of 1.654). No other abilities and skills provided significant nonnegative estimates.

As Table 5 shows, SAT math score was also a predictor of nonengineering study, although this variable had a far larger standard error than in the previous model (Table 4), making it only just significant at the .05 level. Other significant predictors differed from those for graduate study in engineering. For co-curricular activities, undergraduate research no longer had a significant result. Instead, the model indicated that participation in nonengineering community

Table 5 Other Graduate School Attendance

Independent variables	β	SE	Odds ratio	Inverse odds ratio
Math proficiency				
SAT math score	0.005	0.003*	1.005	
Co-curricular participation				
Undergraduate research	−0.001	0.012		
Engineering internships	−0.012	0.013		
Cooperative educational experiences	−0.002	0.025		
Nonengineering community volunteer work	0.016	0.008*	1.016	
Engineering club or student chapter of a professional society	0.169	0.066**	1.184	
Abilities and skills				
Design skills	0.338	0.319		
Contextual awareness	0.205	0.160		
Interdisciplinary skills	−0.377	0.290		
Teamwork skills	−0.373	0.227		
Communication skills	−0.377	0.220		
Leadership skills	0.368	0.306		

Notes: This dependent variable includes programs that were partially but not fully related to engineering. The reference category is no graduate study. Analytical model includes controls for institution and individual engineer's demographics. Odds ratios and inverse odds ratios are provided only for significant estimators.
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

volunteer work was a positive predictor of enrollment in nonengineering graduate study, in comparison with no graduate study. A one-month increase in engineers' participation in nonengineering community volunteer work led to a 2% increase. None of the independent variables related to abilities and skills provided significant nonnegative estimates.

In sum, the effect of the independent variables in our model varied considerably depending on whether engineers' graduate study did or did not focus on engineering. Given that the measures of self-assessments of skills are closely related to engineering context, we found that their self-beliefs in the senior year influenced their likelihood of enrolling in engineering graduate study, but not in other fields of study. While undergraduate research experiences positively related to graduate school enrollment in engineering, participation in clubs and volunteer work positively related to nonengineering graduate study.

Discussion

This study aimed to investigate how engineers' math proficiency prior to college, self-assessments of skills during college, and co-curricular participation during college influence their attendance in graduate school. Research has explained three influences on decisions to pursue graduate study in STEM: mathematics proficiency, match between qualifications and interests, and demand factors. Our first research question addressed the math proficiency explanation. We confirmed that mathematics proficiency prior to college, as measured by SAT mathematics scores, influences enrollment in graduate programs. However, the respective significance levels ($p < .001$ for engineering, $p < .05$ for nonengineering) made us more confident in asserting that prior math proficiency matters more to engineering graduate school than to other fields of graduate study. This result has implications for opportunities to attend graduate school among historically underrepresented racial minority groups, since prior research has shown that SAT math scores differ by racial/ethnic groups. Research usually called attention to African American students' lack of math preparation for collegiate mathematics courses (McGee & Martin, 2011), which ultimately can discourage their graduate school choice in STEM fields. Issues of social and cultural capital must also be considered though, because access to the preparatory math courses and SAT math scores are tied to larger contextual factors such as parental education and expectations, school location and resources, and the distribution of household wealth (Oakes, 2003).

Interestingly, SAT verbal scores, as a proxy for verbal ability, were not significant predictors for engineering graduate school attendance, but were significant predictors of nonengineering graduate school attendance. This finding was based on our analyses that controlled for race as well as gender. This finding supports previous research identifying academic preparedness in mathematics as one of the most salient factors influencing graduate school attendance (Huang, Taddese, & Walter, 2000).

Our second research question explored whether a match between qualifications and interests influenced graduate school attendance in engineering. We included measures of students' engagement in a variety of co-curricular activity and graduates' self-assessments of their engineering abilities as undergraduates. We address each set of variables below.

Engineers' undergraduate co-curricular experiences were positively related to their interests in graduate study. The more time students spent in undergraduate research, the more likely they were to be enrolled or have completed a graduate program in engineering. This pattern was consistent with previous studies on the effect of undergraduate research on graduate school enrollment (Boylan, 2009; Lopatto, 2007) and students' intention to enroll in a STEM graduate program (Eagan et al., 2013; Jiang & Loui, 2012). Our finding also supports the notion that undergraduate research is an effective tool to increase students' interests in engineering graduate studies.

The more time engineering undergraduates spent in nonengineering community volunteer work, the more likely they were to have attended a nonengineering graduate program within three years after graduation. Engineering undergraduates who participated in such activities may have interests outside the field that they cultivated during their studies, or they may become interested in other fields or occupations as a result of their involvement in nonengineering activities. Pursuing a nonengineering graduate program, however, does not necessarily indicate that an individual leaves the field. We found that 66% of students who choose nonengineering master's degrees took management or business-oriented master's programs. This large percentage may suggest that such students wanted to prepare themselves for engineering leadership positions rather than new nonengineering career directions. Future research might explore how different kinds of co-curricular involvement shape ideas about careers and what kinds of preparation during college are needed for different career paths.

Our analysis of engineers' self-ratings of several engineering skills permits a fine-grained look at how different qualifications influence graduate study in the field, and our findings indicated that high levels of confidence in different engineering skills had different effects on engineering graduate school attendance. Engineers who reported higher teamwork skills were less likely to have attended an engineering graduate program three years after graduation. In contrast, higher self-reported leadership skills increased the probability that an engineer had completed or was enrolled in an engineering graduate program within three years of receiving a bachelor's degree.

These findings appear generally consistent with theories of vocational choice that posit that individuals gravitate toward careers consistent with their vocational aspirations, interests, competencies, and self-perceptions (Holland, 1997). Our findings regarding engineers' perceptions of their qualifications for graduate study are also largely consistent with the predictions of self-efficacy theory. Engineers who reported high levels of confidence in their leadership skills during college might choose graduate school soon after completing their bachelor's degree to prepare for higher positions in the engineering industry. Those who rated themselves highly on teamwork skills appear to select different career paths, at least early in their postgraduate years. The effect of teamwork self-assessments beyond this early-career period is worthy of further study to determine how such assessments influence further career decisions.

Implications

Future Study

One important question our study cannot answer is how nonengineering graduate study may complement engineering undergraduate study to advance a career in engineering. Pursuing a nonengineering graduate program does not necessarily indicate an individual's intention to leave the field. Indeed, since management skills are critical to career advancement in technically oriented industries, many engineers pursue graduate studies in business to continue their careers within these fields. Similarly, individuals may pair an undergraduate degree in engineering with graduate study in medicine or science to prepare for work in bioengineeirng and biomedical engineering. National agencies should support future research to understand why engineering graduates pursue advanced education in other fields, in order to further promote domestic production of human resources and help individuals attain their educational and career goals.

Although we report on graduate school attendance three years after graduation, we likely underestimate the number of engineering graduates who eventually pursue graduate study in the field: some engineers begin graduate study in engineering more than four years after graduation. This study also does not include 104 engineers who had attended graduate schools for both engineering and nonengineering graduate degrees. This group might have strong interests and qualifications for interdisciplinary learning. Future research needs to investigate which kinds of college experiences and qualifications encourage engineering graduates to choose between engineering and nonengineering graduate education.

Since we have found that engineers' perceptions of the curricular emphasis placed on particular engineering knowledge and skills were not significant influences on graduate education in engineering (Ro & Lattuca, 2010), we did not include the influence of curricular experience in this study. Future research, however, should examine the undergraduate educational experience more deeply and examine the influence of instructional methods and classroom climate, as well as course content, on graduates' decisions to pursue graduate education. Researchers have suggested that students in programs with relatively stronger emphases on professional skills and values might tend toward engineering employment immediately after graduation rather than begin graduate study (Kranov, Hauser, Olsen, & Girardeau, 2008; Nehdi & Rehan, 2007). Collaborative and problem-based learning in engineering courses may influence students' interests and confidence in professional and interpersonal skills and, ultimately, their decisions about graduate school attendance in engineering.

We also suggest several future research ideas arising from the limitation of our data. First, nationally representative, multi-institutional, and longitudinal data should be collected. Because our data were cross-sectional, we cannot assume that the relationship between self-assessed skills and engineering graduate school choice was causal. Longitudinal studies could be designed to ask senior engineering students to report their college experience and assess their knowledge and skills, and then to measure their graduate school choice pattern after three and seven years to study both early and middle career paths. Such studies should collect a finer-grained pattern of graduate school choice, such as part- and full-time enrollment status, and specific categories of nonengineering graduate programs. Future research also should investigate how students handle the tuition costs of graduate school study.

Practice and Policies

This study also has implications for policy and practice in three areas: students' math proficiency prior to college education, disciplinary domain knowledge and skills during college, and co-curricular programs. In our models, the explanatory power of SAT math scores is considerable, even after controlling for performance during undergraduate study. This result suggests that one of the most effective ways to increase the numbers attending engineering graduate programs is to improve the quality of math education at the K–12 level. We acknowledge though that prior research has shown just how difficult this is to achieve (e.g., Ball & Forzani, 2009; Dee & Jacob 2011; Hoxby, 2000; Porter, McMaken, Hwang, & Yang, 2011).

It may be equally important to help high school and college students understand that more than mathematics proficiency is required for engineering practice and advancement, as many national reports on engineering education make clear (Jamieson & Lohmann, 2012; NAE, 2004). In response to industry demands and changes in professional program accreditation standards, engineering curricula now emphasize to varying degrees not only mathematical, scientific, and technical knowledge, but also professional skills. An important finding from this study confirms that students' leadership competence positively relates to their choice of graduate education in engineering. Incorporating more leadership development components in undergraduate curricula may encourage more students to pursue graduate study – and leadership positions – in science and technology fields. Expanding students' understanding of what leadership entails is also critical. Students who have high confidence in their teamwork skills appear to see its benefit for their competence in work environments, but not apparently for graduate school. Engineering faculty members should convey the message that graduate work in engineering requires not only individual initiative and leadership skills, but also teamwork on multidisciplinary teams and in collaboration with real clients.

These findings have implications for student affairs professionals and others who facilitate students' curricular and co-curricular learning; they can help students gain insights into what STEM-related graduate study and careers entail by promoting undergraduate research and other co-curricular opportunities. Students' co-curricular experiences might also influence their graduate school choice through the skills that they develop. One study found that participation in undergraduate research opportunities had a positive influence on students' communication skills, but no influence on their teamwork and leadership skills (Carter, Ro, Alcott, & Lattuca, 2016). Although research supports that undergraduate research experiences help students attend graduate school, promoting leadership skills would be more beneficial for engineering students to choose graduate study.

Conclusions

STEM undergraduate and graduate programs have played a key role in maintaining the United States as a global leader in science and technology. Although previous research suggested several explanations of how students in STEM fields choose to pursue graduate education, college experiences and self-assessed skills did not receive attention. This study confirms that higher math proficiency, higher self-assessments of certain skills, and participation in specific co-curricular programs influence graduate school attendance. This study provides a new approach to exploring the influence of co-curricular experiences and self-assessments of skills during college on engineering and nonengineering graduate study. More research is needed to understand the pathways from undergraduate education to graduate programs after graduation from engineering programs.

Appendix
Model Variables and Coding Procedures

Dependent variable	
Engineer's graduate-school decision	Non-ordered categorical: currently enrolled in or received degree in engineering graduate school, currently enrolled in or received degree outside of engineering graduate school, or working without any graduate study
Independent variables	
Math proficiency	
SAT score	Continuous
Co-curricular participation	
Undergraduate research	Continuous, measured in months
Engineering internships	Continuous, measured in months
Cooperative educational experiences	Continuous, measured in months
Nonengineering community volunteer work	Continuous, measured in months
Engineering club or student chapter of a professional society	Ordinal, 1 = not active to 5 = extremely active
Abilities and skills	
Design skills	Factor consisting of student self-rating for 12 items: (1) evaluating design solutions based on a specified set of criteria; (2) generating and prioritizing criteria for evaluating the quality of a solution; (3) producing a product; (4) applying systems thinking in developing solutions to an engineering problem; (5) brainstorming possible engineering solutions; (6) taking into account the design contexts and the constraints they may impose on each possible solution; (7) defining design problems and objectives clearly and precisely; (8) asking questions to understand what a client/customer really wants in a 'product'; (9) breaking down a design project into manageable components or tasks; (10) recognizing when changes to the original understanding of the problem may be necessary; (11)

Appendix (continued)

	developing pictorial representations of possible designs; and (12) undertaking a search before beginning team-based brainstorm. Each item is ordinal, from 1 = weak to 5 = excellent.
Contextual awareness	Factor consisting of student self-rating for four items: (1) using what you know about different cultures, social values, or political systems in developing engineering solutions; (2) recognizing how different contexts can change a problem solution; (3) knowledge of contexts that might affect the solution to an engineering problem; and (4) knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit. Each item is ordinal, from 1 = weak to 5 = excellent
Interdisciplinary skills	Factor consisting of student self-rating for eight items: (1) I can take ideas from outside engineering and synthesizing them in ways that help me better understand or explain a problem; (2) I can use what I have learned in one field in another setting or to solve a new problem; (3) I see connections between ideas in engineering and ideas in the humanities and social sciences; (4) I enjoy thinking about how different fields approach the same problem in different ways; (5) Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem; (6) Not all engineering problems have purely technical solutions; (7) In solving engineering problems I often seek information from experts in other academic fields; and (8) I value reading about topics outside of engineering. Each item is ordinal, from 1 = strongly agree to 5 = strongly disagree
Teamwork skills	Factor consisting of student self-rating for five items: (1) working with others to accomplish group goals; (2) working in teams of people with a variety of skills and backgrounds; (3) working in teams where knowledge and ideas from multiple engineering fields must be applied; (4) working in teams that include people from fields outside engineering; and (5) putting aside differences within a design team to get the work done. Each item is ordinal, from 1 = weak to 5 = excellent
Communication skills	Factor consisting of student self-rating for six items: (1) writing a well-organized, coherent report; (2) making effective audiovisual presentations; (3) constructing

Appendix (continued)

	tables or graphs to communicate a solution; (4) communicating effectively with clients, teammates, and supervisors; (5) communicating effectively with nontechnical audiences; and (6) communicating effectively with people from different cultures or countries. Each item is ordinal, from 1 = weak to 5 = excellent
Leadership skills	Factor consisting of student self-rating for six items: (1) helping your group or organization work through periods when ideas are too many or too few; (2) developing a plan to accomplish a group or organization's goals; (3) taking responsibility for group's or organization's performance; (4) motivating people to do the work that needs to be done; (5) identifying team members' strengths or weaknesses and distribute tasks and workload accordingly; and (6) monitoring the design process to ensure goals are being met. Each item is ordinal, from 1 = weak to 5 = excellent
Control variables	
Female	Dichotomous, 1 = yes, 0 = no
Racial/ethnic minority	Refers to all non-White students. Dichotomous, 1 = yes, 0 = no
Mother and/or father has at least a bachelor's degree	Dichotomous, 1 = yes, 0 = no
High school GPA at least 3.5	Dichotomous, 1 = yes, 0 = no
Engineering program	Non-ordered categorical: electrical engineering (reference group), mechanical engineering), chemical engineering, civil engineering, others (bioengineering and biomedical engineering, industrial engineering, general engineering)
Large institution	Dichotomous, 1 = yes, 0 = no
Doctorate-degree awarding institution	Dichotomous, 1 = yes, 0 = no

Acknowledgments

This study was supported by a grant from the National Science Foundation grant 0550608. The opinions expressed here do not reflect the opinions or policies of the NSF, and no official endorsement should be inferred. The authors wish to acknowledge the contributions of the members of the research team who participated in various stages of the development of the design, instruments, and databases for this project: Patrick T. Terenzini, Betty J. Harper, Alexander C. Yin, Gul Kremer, Thomas A. Litzinger, India McHale, David B. Knight, and David C. Perez II. Daniel Merson and Travis York also served as graduate research assistants on the project team.

References

ABET. (2009). *Criteria for accrediting engineering programs: Effective for evaluations during the 2010–2011 accreditation cycle*. http://www.abet.org/wp-content/uploads/2015/04/criteria-eac-2010-2011.pdf

Adedokun, O. A., Bessenbacher, A. B., Parker, L. C., Kirkham, L. L., & Burgess, W. D. (2013). Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *Journal of Research in Science Teaching*, *50*(8), 940–951. http://dx.doi.org/10.1002/tea.21102. ISSN: 0022-4308

Adelman, C. (1998). *Women and men of the engineering path: A model for analyses of undergraduate careers*. http://files.eric.ed.gov/fulltext/ED419696.pdf

Anakwe, U. P., & Greenhaus, J. H. (2000). Prior work experience and socialization experiences of college graduates. *International Journal of Manpower*, *21*(2), 95–111. http://dx.doi.org/10.1108/01437720010331035

Anderson, E., & Kim, D. (2006). *Increasing the success of minority students in science and technology*. Washington, DC: American Council on Education.

Anderson, V. (1994). How engineering education shortchanges women. *Journal of Women and Minorities in Science and Engineering*, *1*(2), 99–121. http://dx.doi.org/10.1615/JWomenMinorScienEng.v1.i2.20

Armor, D. J. (1974). Theta reliability and factor scaling. In H. Costner (Ed.), *Sociological methodology: 1973–1974* (pp. 17–50). San Francisco, CA: Jossey-Bass.

Astin, A. W., & Astin, H. S. (1992). *Undergraduate science education: The impact of different college environments on the educational pipeline in the sciences*. Los Angeles, CA: University of California, Graduate School of Education, Higher Education Research Institution.

Bair, C. R., & Haworth, J. G. (2005). Doctoral student attrition and persistence: A meta-analysis of research. *Higher Education: Handbook of Theory and Research*, *19*, 481–534. http://dx.doi.org/10.1007/1-4020-2456-8_11

Baker, S., Tancred, P., & Whitesides, S. (2002). Gender and graduate school: Engineering students confront life after the B. Eng. *Journal of Engineering Education*, *91*(1), 41–47.

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education*, *60*(5), 497–511. http://dx.doi.org/10.1177/0022487109348479

Bandura, A. (1986). *Social foundations of thought and action*. Englewood Cliffs, NJ: Prentice Hall.

Baruch, Y. (1999). Response rate in academic studies – A comparative analysis. *Human Relations*, *52*, 421–438. http://dx.doi.org/10.1177/001872679905200401

Bauer, K. W., & Bennett, J. S. (2003). Alumni perceptions used to assess undergraduate research experience. *Journal of Higher Education*, *74*(2), 210–230. http://dx.doi.org/10.1353/jhe.2003.0011

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1–40. http://dx.doi.org/10.1023/A:1021302408382

Bowen, W. G., Chingos, M. M., & McPherson, M. S. (2009). *Crossing the finish line: Completing college at America's public universities*. Princeton, NJ: Princeton University Press.

Boylan, M. (2009). Undergraduate STEM research experiences: Impact on student interest in doing graduate work in STEM fields. In R. G. Ehrenberg, C. V. Kuh, & Cornell Higher Education Research Institute (Eds.), *Doctoral education and the faculty of the future* (pp. 109–120). Ithaca, NY: Cornell University Press.

Bozick, R., & Ingels, S. J. (2007). *Mathematics coursetaking and achievement at the end of high school: Evidence from the education longitudinal study of 2002*. Washington, DC: National Center for Education Statistics.

Brown, S. D., Lent, R. W., & Gore, P. A. (2000). Self-rated abilities and self-efficacy beliefs: Are they empirically distinct? *Journal of Career Assessment*, *8*(3), 223–235. http://dx.doi.org/10.1177/106907270000800302

Carter, D. F., Ro, H. K., Alcott, B. M., & Lattuca, L. R. (2016). Co-curricular connections: The role of undergraduate research experiences in promoting engineering students' communication, teamwork, and leadership skills. *Research in Higher Education*, *57*, 363–393. http://dx.doi.org/10.1007/s11162-015-9386-7

Chen, X., & Weko, T. (2009). *Students who study science, technology, engineering, and mathematics (STEM) in postsecondary education*. Washington, DC: National Center for Education Statistics.

Correll, S. J. (2004). Constraints into preferences: Gender, status, and emerging career aspirations. *American Sociological Review*, *69*(1), 93–113. http://dx.doi.org/10.1177/000312240406900106

Cox, B. E., McIntosh, K., Reason, R. D., & Terenzini, P. T. (2014). Working with missing data in higher education research: A primer and real-world example. *Review of Higher Education 37*(3), 377–402. http://dx.doi.org/10.1353/rhe.2014.0026

Davies, S., & Guppy, N. (1997). Fields of study, college selectivity, and student inequalities in higher education. *Social Forces*, *75*(4), 1417–1438. http://dx.doi.org/10.1093/sf/75.4.1417

Dee, T. S., & Jacob, B. (2011). The impact of No Child Left Behind on student achievement. *Journal of Policy Analysis and Management*, *30*(3), 418–446. http://dx.doi.org/10.1002/pam.20586

Dempster, A. P., Laird, N. M., & Rubin, D. B. (1977). Maximum likelihood from incomplete data via the EM algorithm. *Journal of the Royal Statistical Society. Series B (Methodological)*, *39*(1), 1–38. http://www.jstor.org/stable/2984875

DesJardins, S. L. (2001). *A comment on interpreting odds-ratios when logistic regression coefficients are negative*. Long Beach, CA: Association for Institutional Research.

Dey, E. L. (1997). Working with low survey response rates: The efficacy of weighting adjustments. *Research in Higher Education*, *38*(2), 215–227. http://dx.doi.org/10.1023/a:1024985704202.

Dix, L. S. (Ed.). (1987). *Minorities: Their underrepresentation and career differentials in science and engineering: Proceedings of a workshop*. Washington, DC: National Academy Press.

Dixon-Román, E. J., Everson, H. T., & McArdle, J. J. (2013). Race, poverty and SAT scores: Modeling the influences of family income on black and white high school students' SAT performance. *Teachers College Record*, *115*(4), 1–33.

Eagan, M. K., Hurtado, S., Chang, M. J., Garcia, G. A., Herrera, F. A., & Garibay, J. C. (2013). Making difference in science education: The impact of undergraduate research programs. *American Educational Research Journal*, *50*(4), 683–713. http://dx.doi.org/10.3102/0002831213482038

Freedle, R. (2003). Correcting the SAT's ethnic and social-class bias: A method for reestimating SAT scores. *Harvard Educational Review*, *73*(1), 1–43.

Gellin, A. (2003). The effect of undergraduate student involvement on critical thinking: A meta-analysis of the literature 1991–2000. *Journal of College Student Development*, *44*(6), 746–762. http://dx.doi.org/10.1353/csd.2003.0066

Graham, J. W. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology*, *60*(1), 549–576. http://dx.doi.org/10.1146/annurev.psych.58.110405.085530

Guinier, L., & Torres, G. (2002). *The miner's canary: Enlisting race, resisting power, transforming democracy*. Cambridge, MA: Harvard University Press.

Herzig, A. H. (2004). Becoming mathematicians: Women and students of color choosing and leaving doctoral mathematics. *Review of Higher Education*, *74*(2), 171–214. http://dx.doi.org/10.3102/00346543074002171

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, *60*(4), 549–571. http://dx.doi.org/10.3102/00346543060004549

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments* (3rd ed.). Odessa, FL: Psychological Assessment Resources.

Hoxby, C. M. (2000). The effects of class size on student achievements: New evidence from population variation. *Quarterly Journal of Economics*, *115*(4), 1239–1285. http://dx.doi.org/10.1162/003355300555060

Huang, G., Taddese, N., & Walter, E. (2000). Entry and persistence of women and minorities in college science and engineering education. *Education Statistics Quarterly*, *2*(3), 59–60.

Jamieson, L. H., & Lohmann. J. R. (2012). *Innovation with impact: Creating a culture of scholarly and systematic innovation in engineering education*. American Society for Engineering Education. https://www.asee.org/member-resources/reports/Innovation-with-Impact

Jiang A., & Loui, M. C. (2012). *What should I do next? How advanced engineering students decide their post-baccalaureate plans*. Paper presented at the Frontiers in Education Conference, Seattle, WA.

Kardash, C. M. (2000). Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology*, *92*(1), 191–201. http://dx.doi.org/10.1037/0022-0663.92.1.191

Kranov, A. A., Hauser, C., Olsen, R., & Girardeau, L. (2008). *A direct method for teaching and assessing professional skills in engineering programs*. ASEE Annual Conference, Pittsburg, PA. https://peer.asee.org/a-direct-method-for-teaching-and-assessing-professional-skills-in-engineering-programs

Kremer, J. F., & Bringle, R. G. (1990). The effects of an intensive research experience on the careers of talented undergraduates. *Journal of Research and Development in Education*, *24*(1), 1–5.

Lattuca, L. R., Knight, D. B., & Bergom, I. (2013). Developing a measure of interdisciplinary competence. *International Journal of Engineering Education*, *29*(3), 726–739.

Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2006). *Engineering change: A study of the impact of EC2000*. Baltimore, MD: ABET.

Lent, R. W., & Brown, S. D. (2006). On conceptualizing and assessing social cognitive constructs in career research: A measurement guide. *Journal of Career Assessment*, *14*(1), 12–35. http://dx.doi.org/10.1177/1069072705281364

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Social cognitive approach to career development: An overview. *Career Development Quarterly*, *44*(4), 310–321. http://dx.doi.org/10.1002/j.2161-0045.1996.tb00448.x

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, *3*(4), 270–277. http://dx.doi.org/10.1187/cbe.04-07-0045

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE-Life Science Education*, *6*(4), 297–306. http://dx.doi.org/10.1187/cbe.07-06-0039

Lowell, B. L., & Salzman, H. (2007). *Into the eye of the storm: Assessing the evidence on science and engineering education, quality, and workforce demand*. Washington, DC: Urban Institute.

Lowell, B. L., Salzman, H., Bernstein, H., & Henderson, E. (2009). *Steady as she goes? Three generations of students through the science and engineering pipeline*. http://dx.doi.org/doi:10.7282/T31R6S4K

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy. *Journal of Engineering Education*, *98*(1), 27–38.

Mau, W. C. (2003). Factors that influence persistence in science and engineering career aspirations. *Career Development Quarterly*, *51*(3), 234–243. http://dx.doi.org/10.1002/j.2161-0045.2003.tb00604.x

McGee, E. O., & Martin, D. B. (2011). "You would not believe what I have to go through to prove my intellectual value!" Stereotype management among academically successful black mathematics and engineering students. *American Educational Research Journal*, *48*(6), 1347–1389. http://dx.doi.org/10.3102/0002831211423972

Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011). *Racial and ethnic minority students' success in STEM education*. San Francisco, CA: Wiley.

National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: National Academies Press.

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education in the new century*. Washington, DC: National Academies Press.

National Science Board. (2014). *Science and engineering indicators: 2014*. http://www.nsf.gov/statistics/seind14/

Nehdi, M., & Rehan, R. (2007). Raising the bar for civil engineering education: Systems thinking approach. *Journal of Professional Issues in Engineering Education and Practice*, *133*(2), 116–125. http://dx.doi.org/10.1061/(asce)1052-3928(2007)133:2(116)

Oakes, J. (2003). *Critical conditions for equity and diversity in college access: Informing policy and monitoring results*. UC/ACCORD. https://ucaccord.gseis.ucla.edu/publications/critical-conditions-for-equity-and-diversity

Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students. A third decade of research*. San Francisco, CA: Jossey-Bass.

Pearson Jr., W. (1987). The graduate education and career patterns of underrepresented minorities in science and engineering. In L. S. Dix (Ed.), *Minorities: Their underrepresentation and career differentials in science and engineering: Proceedings of a Workshop*. Washington, DC: National Academy Press.

Pearson Jr., W., & Fechter, A. (1994). *Who will do science? Educating the next generation*. Baltimore, MD: Johns Hopkins University Press.

Perna, L. W. (2004). Understanding the decision to enroll in graduate school: Sex and racial/ethnic group differences. *Journal of Higher Education*, *75*(5), 487–527. http://dx.doi.org/10.1353/jhe.2004.0032

Porter, A., McMaken, J., Hwang, J., & Yang, R. (2011). Common Core standards: The new U.S. intended curriculum. *Educational Researcher*, *40*(3), 103–116. http://dx.doi.org/10.3102/0013189X11405038

Porter, S. R., & Umbach, P. D. (2006). Student survey response rates across institutions: Why do they vary? *Research in Higher Education*, *47*, 229–247. http://dx.doi.org/10.1007/s11162-005-8887-1

Renniger, K. A. (2000). Individual interest and its implication for understanding intrinsic motivation. In J. M. Harackiewicz & C. Sansone (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 373–404). San Diego, CA: Academic Press.

Ro, H. K., & Lattuca, L. R. (2010). *The impact of college experiences and engineering skills on enrollment in engineering graduate programs*. Paper presented at the Annual Conference of the Association for the Study of Higher Education, Indianapolis, IN.

Ro, H. K., Merson, D. S., Lattuca, L. R., & Terenzini, P. T. (2015). Validity of the contextual competence scale for engineering students. *Journal of Engineering Education*, *104*(1), 35–54. http://dx.doi.org/10. 1002/jee.20062

Salzman, H., Kuehn, D., & Lowell, B. L. (2013). *Guestworkers in the high-skill U.S. labor market* (Briefing paper 359). Economic Policy Institute. http://www.epi.org/publication/bp359-guestworkers-high-skill-labor-market-analysis/

Sax, L. J. (1994). Predicting gender and major-field differences in mathematical self-concept during college. *Journal of Women and Minorities in Science and Engineering*, *1*(4), 291–307. http://dx.doi.org/10.1615/JWomenMinorScienEng.v1.i4.30

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Seymour, E., Hunter, A. B., Laursen, S., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493–534. http://dx.doi.org/10.1002/sce.10131

Sheppard, S., Gilmartin, S., Chen, H. L., Donaldson, K., Lichtenstein, G., Eris, Ö., Lande, M., & Toye, G. (2010). *Exploring the engineering student experience: Findings from the Academic Pathways of People Learning Engineering Survey (APPLES)* (TR-10-01). Seattle, WA: Center for the Advancement of Engineering Education.

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills" – Can they be taught? Can they be assessed? *Journal of Engineering Education*, *94*(1), 41–55. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00828.x

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, *94*(1), 87–101. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00831.x

Smith, T. W. (1995). Trends in non-response rates. *International Journal of Public Opinion Research*, *7*(2), 157–171. http://dx.doi.org/10.1093/ijpor/7.2.157

Steele, J., James, J. B., & Barnett, R. C. (2002). Learning in a man's world: Examining the perceptions of undergraduate women in male-dominated academic areas. *Psychology of Women Quarterly*, *26*(1), 46–50. http://dx.doi.org/10.1111/1471-6402.00042

Strauss, L. C., & Terenzini, P. T. (2005). *Measuring student performance on EC2000 criterion 3.a-k*. ASEE Annual Conference, Portland, OR. https://peer.asee.org/measuring-student-performance-on-the-ec2000-3-a-k-criteria

Strayhorn, T. L. (2010). Undergraduate research participation and STEM graduate degree aspirations among students of color. *New Directions for Institutional Research*, *148*, 85–92. http://dx.doi.org/10.1002/ir.364

Swanson, J. L. (1993). Integrated assessment of vocational interests and self-rated abilities and skills. *Journal of Career Assessment*, *1*, 50–65. http://dx.doi.org/10.1177/106907279300100106

Teitelbaum, M. S. (2001). How we (unintentionally) make scientific careers unattractive. In D. E. Chubin & W. Pearson, Jr. (Eds.), *Scientists and engineers for the new millennium*, (pp. 71–79). Washington, DC: Commission on Professionals in Science and Technology.

Tempest, B. Q., Dika, S. L., Pando, M. A., & Lopez, S. T. (2012). *International service as a means of improving retention of engineering students*. ASEE Annual Conference, San Antonio, TX. https://peer.asee.org/21591

Thiry, H., Laursen, S. L., & Hunter, A. B. (2011). What experiences help students become scientists? A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *Journal of Higher Education*, *82*(4), 357–388. http://dx.doi.org/10.1353/jhe.2011.0023

Tracey, T. J. G., & Hopkins, N. (2001). Correspondence of interests and abilities with occupational choice. *Journal of Counseling Psychology*, *48*(2), 178–189. http://dx.doi.org/10.1037/0022-0167.48.2.178

Van Horn, P. S., Green, K. E., & Martinussen, M. (2009). Survey response rates and survey administration in counseling and clinical psychology: A meta-analysis. *Educational and Psychological Measurement*, *69*, 389–403. http://dx.doi.org/10.1177/0013164408324462

von Hippel, P. T. (2009). How to impute interactions, squares, and other transformed variables. *Sociological Methodology*, *39*(1), 1–27. http://dx.doi.org/10.1111/j.1467-9531.2009.01215.x

Wang J., & Staver J. (2001). Examining relationships between factors of science education and student career aspiration. *Journal of Educational Research*, *94*(5), 312–319. http://dx.doi.org/10.1080/00220670109598767

Authors

Hyun Kyoung Ro is an assistant professor of higher education and student affairs at Bowling Green State University, 330 Education Building, Bowling Green State University, Bowling Green, OH 43403; hro@bgsu.edu.

Lisa R. Lattuca is a professor of higher education at the Center for the Study of Higher and Postsecondary Education at the University of Michigan, 610 E. University Ave., Ann Arbor, MI 48109; llatt@umich.edu.

Ben Alcott is a university lecturer in education and international development at the University of Cambridge's Faculty of Education, 184 Hills Road, Cambridge, CB2 8PQ, United Kingdom; bma27@cam.ac.uk.