120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #6119

Not All the Same: A Look at Early Career Engineers Employed in Different Sub-Occupations

Ms. Samantha Brunhaver, Stanford University

Samantha Brunhaver is a fifth year graduate student at Stanford University. She is currently working on her Ph.D. in Mechanical Engineering with a focus in engineering education. Samantha completed a B.S. in Mechanical Engineering from Northeastern University in 2008 and a M.S. in Mechanical Engineering with a focus in Design for Manufacturing from Stanford in 2010.

Dr. Shannon Katherine Gilmartin, Stanford University
Michelle Marie Grau, Stanford University

Michelle Grau is a senior studying mechanical engineering and doing research in engineering education—the perfect combination of her interests.

Dr. Sheri Sheppard, Stanford University

Dr. Sheri Sheppard is in the Design Group of Mechanical Engineering at Stanford. Besides teaching undergraduate and graduate courses on structural analysis and design, she serves an administrative role as Associate Vice Provost for Graduate Education. Her research focuses on the study of educational and career pathways of people interested in technical work (and how to make K-20 education more supportive of these pathways).

Dr. Helen L. Chen, Stanford University

Not All the Same: Early Career Engineers Employed in Different Sub-Occupations

Abstract

In recent years, the preparation of engineering students for professional practice has featured prominently in the engineering education literature. Organizations such as ABET and the National Academy of Engineering have even published lists of skills and characteristics required by graduates to succeed[1-2]. What many studies fail to address, however, are the varying experiences of early career engineering graduates employed in different engineering sub-occupations. While many engineering graduates go on to become engineering practitioners, others pursue careers in engineering consulting, management, research, and teaching, among other options. This paper aims to better understand differences across engineering sub-occupations by comparing them on various personal, experiential, and affective outcomes.

Participants for this study come from a survey of engineering bachelor's graduates who earned their degrees from four U.S. institutions in 2007. Funded by the National Science Foundation and deployed in autumn of 2011, the survey received 484 complete responses which were weighted by gender, major, and institutional size to better approximate aggregate responses. Occupational lists on the survey were constructed based on categories in the NSF Science and Engineering Statistical Data System (SESTAT)[3] which itself is adapted from the U.S. Bureau of Labor Statistics 2000 Standard Occupational Classification[4]. We examined three engineering sub-occupations for this paper: engineering practitioners, consultants, and managers. Four years after graduation, 48 percent of survey respondents were employed in one of these three groups.

Respondents were compared on survey measures related to their demographics, career experiences, work characteristics, and self-perceptions. Results showed several differences, specifically in graduates' perceptions of their work, current positions, and identities. Engineering managers were more likely to rely on competencies such as business knowledge and leadership in their work and less likely to rely on engineering techniques and tools. Additionally, smaller proportions of engineering managers saw their current positions and identities as being engineering-related. The findings suggest that different engineering sub-occupations require different skill sets, which may in turn affect how employees view their jobs and themselves. Determination of these differences can enable new thinking about which skills to emphasize in undergraduate engineering programs, through core courses, electives, and/or extracurricular activities.

Introduction

In response to national calls for engineering education reform[5-6], the training and preparation of engineering students have received much attention. Government, industry, and organizations such as the National Academy of Engineering and ABET agree, tomorrow's practicing engineers should be adept at technical problem solving, design, and analysis, but also at communication, teamwork, and business skills[1-2,7-8]. They should additionally be able to tackle a broad range of social and technological challenges, from environmental sustainability and energy conservation to personal health and safety[9-10]. As Perlow and Bailyn[11] have expressed, “a picture has emerged of the ‘generic’ engineer, the ‘generic’ engineering job, and the ‘generic’ engineering career,” and the role of engineering educators is to equip students with “generic” engineering skills.

There are many reasons why a “generic” framework of engineering is useful[12]. Adhering to it ensures that engineering graduates meet the minimum educational requirements to practice engineering, which in turn gives them credibility with the general public and better employment and career prospects. It also provides a common ground for various stakeholders to give programs feedback and guidance, in addition to promoting a set of best educational practices. Several studies have focused on the quality of engineers’ preparation for the workforce relative to these established norms[13-15].

A significant limitation to the framework, however, is the presumption that engineers’ work and careers are homogeneous, and that all engineers require the same balance of technical and professional skills. The engineering practitioner is often presented as the epitome of this balance, while other engineering careers such as the researcher, manager, or consultant receive less attention[11]. This discrepancy is problematic for engineering education and the engineering profession as students may not be prepared to take up other positions upon graduating. Furthermore, they may experience low career satisfaction[11] or even leave engineering[16-19] if they perceive poor fit between their skills and interests and those traditionally associated with being an engineer. Thus, more in-depth understanding of engineers’ work and careers is needed, as is new thinking about what information to share with students. Such action can not only better prepare students for the engineering workforce, but potentially increase engineering retention.

To date, few studies have compared and contrasted different types of engineers. Using qualitative methods, Bucciarelli investigated how teams approached design at three different engineering firms[20], Anderson et al. examined the work of engineers at six firms[21], and Brunhaver et al. explored differences in the experiences of newly hired engineers at four firms[22-23]. While these studies identified some differences in company structures and disciplinary norms, most of the findings highlight instead commonalities between the firms. Several papers have looked at the differences between engineers employed in different functions[24-28], particularly research and development, sales, and production, and several more have compared engineering practitioners and managers[11,29-33]. However, these papers emphasize differences in the groups’ interests, aptitudes, and values rather than in their job and career-related measures. They also focused primarily on engineers in their mid-to-late career stages.

To begin to fill this gap, this paper examines the similarities and differences among early career engineering graduates employed as engineering practitioners, managers, and consultants. The last two groups are particularly important because they demonstrate that not all engineers wait until later in their careers before pursuing non-practitioner paths. We compared the three groups on measures related to their demographics, career experiences, and work characteristics. We also explored differences in how each group’s work influences their engineering identity, as previous studies have found relationships between work and identity for engineers in general[21,23] and for specific sub-groups[11,30]. The research questions addressed in this paper are:

(1) Do the engineering graduates in each sub-occupation differ in terms of their demographics, career experiences, and work characteristics?
(2) Which competencies do the graduates in each sub-occupation perceive as important to their work?
(3) Do the graduates in each sub-occupation identify their current employed positions as "engineering" and themselves as "engineers"?

Data for this study come from engineering graduates who participated in the National Science Foundation (NSF) funded Pathways of Engineering Alumni Research Survey (PEARS) approximately four years after earning their bachelor's degrees. Implications of this work will focus on suggestions for educational research and practice to better prepare and retain engineers.

Data Source

The analyses in the current study are part of the larger Engineering Pathways Study (EPS), a multi-institutional NSF study investigating early career engineering graduates[34]. The aim of EPS is to improve colleges and universities, as well as workplaces, by facilitating transitions from undergraduate engineering education to the engineering workforce.

The EPS study used a sequential, exploratory mixed-methods design, where findings from interviews with 30 early career engineering graduates were used to develop the Pathways of Engineering Alumni Research Survey, or PEARS, instrument[34-35]. PEARS was designed with two goals: (1) to identify the educational and workplace factors that most influence engineering graduates' initial and future career plans, and (2) to develop a better understanding of their early career work, experiences, and perspectives.

To achieve the first goal, PEARS was framed in Social Cognitive Career Theory, or SCCT, which posits that career goals and actions are influenced directly by self-efficacy, outcome expectations, and interests, and indirectly by personal, experiential, and contextual factors[36]. SCCT was chosen due to its applicability to early career choice and its use in other studies of engineering students[37-41] and engineering professionals[42]. Specific survey items were created based on findings from our interviews with engineering graduates[43-45], findings from the prior Academic Pathways Study including the Academic Pathways of People Learning Engineering Survey[16-18], as well as other career literature[46-48]. Items to achieve the second goal were derived from some of the same sources plus the NSF SESTAT surveys[3], the 2009 Stanford Alumni Survey[49], the ABET Criterion 3 outcomes[1], and the National Academy of Engineering *Engineer of 2020* report[2].

Prior to deployment of the survey, we conducted several rounds of pilot testing with engineering graduates for time and content validity. We also sought feedback on the survey from engineering faculty, deans, and administrators. The final PEARS instrument featured 45 questions covering five domains: (1) degrees and employment, (2) pre- and post-graduation learning experiences, (3) self-efficacy, outcome expectations, and interests, (4) career satisfaction and plans, and (5) background characteristics. Although the overall EPS study was mixed-methods, this paper presents results from the PEARS survey only.

Population and Sample

The PEARS instrument was administered online in autumn of 2011 to engineering graduates four years after earning their engineering bachelor's degrees in 2007. The graduates came from four geographically distributed research universities of varying control, size, and type. All four institutions had been partners in the earlier Academic Pathways Study[16,50] and agreed to participate in EPS as part of a longer-term research collaborative.

Together our four partner schools graduated 2,520 engineering bachelor's students in 2007, and we had working e-mail addresses for 1,801 of them. Of these 1,801 alumni, a total of 543 engineering graduates responded to the survey. We weighted this respondent sample for differential response rates by gender and major and differential sampling rates across institutions. The final PEARS sample was comprised of 484 survey respondents who provided complete responses to the PEARS instrument[i]; applying weights, the total weighted n was 2,249. Chen et al.[35] provides further details about the PEARS deployment.

For the current study, we defined our focal sample as those graduates across our four partner schools who were employed full- or part-time as engineering practitioners, consultants, and managers at the time of the survey. Occupational lists on the survey were constructed based on categories in the NSF Science and Engineering Statistical Data System (SESTAT)[3] which itself is adapted from the U.S. Bureau of Labor Statistics 2000 Standard Occupational Classification[4]. Respondents could indicate engineering practice, consulting, or management as their current and primary employed position, either (1) by selecting engineering as their primary field and engineering practice, consulting, first-line management, or mid-level management as their sub-field, and (2) by selecting consulting, first-line management, or mid-level management as their primary field and engineering as their sub-field. The occupational field and engineering sub-field lists are shown in Table 1 and Table 2, respectively, and were presented to respondents as drill down menus. As seen in Table 2, respondents could choose from other engineering sub-fields, but these were excluded from the analysis due to either small sample sizes (researchers, technologists) or heterogeneous compositions (other engineers, sub-occupation unknown).

Table 1. Occupation fields

Architects	Managers, top-level executives and administrators
Artists, entertainers, athletes and media workers	Mathematical scientists
Biological and life scientists	Military personnel
Business and financial operations specialists	Physical scientists
Clerical/Administrative workers	Research associates and assistants
Clergy/Other religious workers	Research assistantships and fellowships (students)
Computer-related occupations	Sales occupations, including sales/commodities
Consultants	Service workers, except health
Counselors	Social scientists
Engineers or engineering-related technologists	Social workers
Farmers, foresters, and fishermen	Teaching assistantships and fellowships (students)
Health workers	Teachers – precollege
Legal workers	Teachers and professors – postsecondary
Library workers	Teachers – others
Managers and supervisors, first-line	Other professions
Managers and supervisors, mid-level	Other occupations

Note: Fields that respondents in our final sample selected are highlighted.

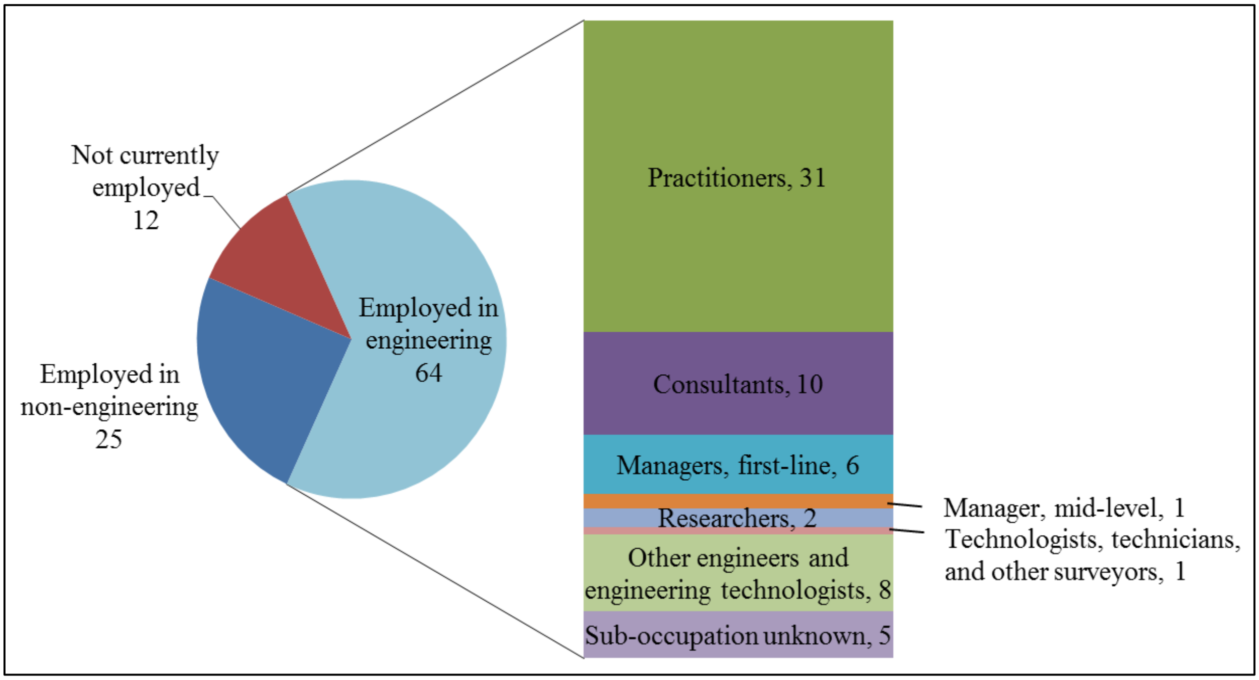
Table 2. Engineering sub-occupation fields

Engineering practitioners
Engineering consultants
Engineering managers, first-line
Engineering managers, mid-level
Engineering research associates and assistants
Engineering teachers and professors
Engineering technologists, technicians, and surveyors
Other engineers or engineering-related technologists

Note: Sub-fields that respondents in our final sample selected are highlighted.

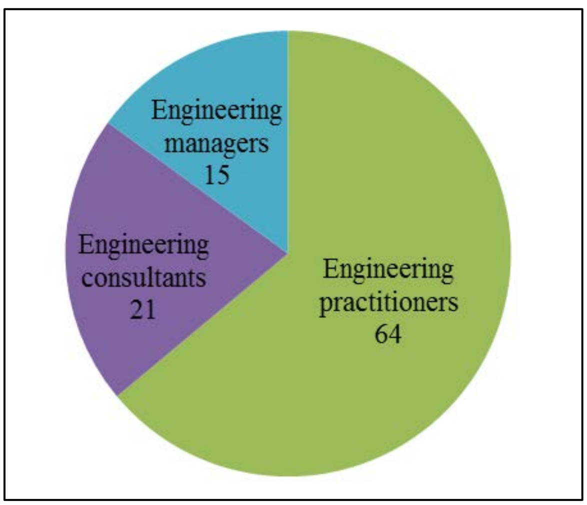
We combined first-line and mid-level engineering managers into a single group called "managers". First-line engineering managers typically supervise engineering teams and projects, whereas the NSF describes mid-level engineering managers as overseeing other engineering managers[51]. Focusing only on engineering practitioners, consultants, and managers reduced our weighted sample by approximately half, from 2,249 to 1,096. Figure 1 shows the percentage distribution of all PEARS graduates according to their employment status, occupation, and engineering sub-occupation (if applicable). Figure 2 shows the percentage distribution of respondents in our focal sample.

Figure 1. Percentage distribution of PEARS respondents by employment status, occupation, and sub-occupation (if applicable) (weighted n=2,249).



Note: Percentages may not total 100% due to rounding.

Figure 2. Percentage distribution of PEARS respondents employed as engineering practitioners, consultants, or managers (weighted n=1,096).



Compared to all other engineering graduates who completed the PEARS survey, graduates in our focal sample were more likely to be male (82% versus 72%) and less likely to be of Asian/Asian American (14% versus 22%) or Black/African American (1% versus 4%) descent. They were less likely to have earned degrees in bio-related engineering (2% versus 7%) or industrial and manufacturing engineering (4% versus 9%), and more likely to have earned degrees in mechanical engineering (22% versus 15%) and civil engineering (17% versus 4%).

Methods

This paper explores the similarities and differences among early career engineering graduates employed as engineering practitioners, consultants, and managers. In particular, respondents in each group were compared on key measures related to their demographics, career experiences, and work characteristics, as well as the perceptions they have about the competencies most important to their work, their current position, and their engineering identity. Non-parametric Kruskal-Wallis and Pearson's chi-square tests were conducted when assumptions could be met due to non-normality in the distribution of all responses, and significant main effects were followed up with *post hoc* Mann-Whitney, Pearson's chi-square, or Fisher's exact tests, as appropriate. We also ran tests between select engineering sub-occupations and their non-engineering counterparts (e.g., engineering managers versus non-engineering managers) using Mann-Whitney tests and Fisher's exact tests, to gain further insights. An alpha of $p<0.05$ denoted statistical significance, and a Bonferroni's adjustment was used wherever multiple comparisons were made (i.e., 0.05 divided by the number of comparisons).

All tests were run using adjusted sample weights to minimize the possibility of artificially inflated effect sizes. They were also run on both the weighted data and the unweighted data to confirm that the weights did not affect inferences. During the first week of survey administration, all instances of the phrase "professional path" in the instrument were replaced with "career path," to potentially improve participant understanding and increase response rates. We conducted our tests with and without the pre-wording change responses to assess how the change may have impacted the data, and since our analyses showed few differences, we retained all responses for reporting.

Demographic measures

The PEARS instrument contained several demographic measures. In this study, we compared for those employed in different engineering sub-occupations their gender (female/male), race/ethnicity, and undergraduate engineering major. Respondents were instructed to "mark all that apply" from six racial/ethnic identities: American Indian/Alaska Native, Black/African American, Hispanic/Latino(a), Native American/Pacific Islander, White, and "other"[16]. Graduates marking more than one option or "other" were later combined into a single category. For undergraduate engineering major, respondents could choose from 24 engineering disciplines, shown in Table 3. These disciplines correspond to those used in the NSF SESTAT[3], in addition to majors unique to our partner institutions; they were presented to respondents in dropdown menu format.

Table 3. Engineering major fields

Aerospace, aeronautical, and astronautical engineering	General engineering
Agricultural engineering	Geophysical and geological engineering
Architectural engineering	Industrial and manufacturing engineering
Bioengineering and biomedical engineering	Materials engineering
Chemical engineering	Mechanical engineering
Civil engineering	Metallurgical engineering
Computer and systems engineering	Mining and minerals engineering
Construction engineering	Naval architecture and marine engineering
Electrical, electronics, and communications engineering	Nuclear engineering
Engineering sciences, mechanics, and physics	Petroleum engineering
Environmental engineering	Other engineering

Career milestone and experience measures

The PEARS instrument included questions about milestones and experiences that respondents may have had since graduating. We examined whether respondents had been promoted or offered a salary raise within an organization, had voluntarily left or involuntarily left an organization, had attended graduate school while working full-time in non-university employment, had started or co-founded a company, or had pursued professional licensure or certification. We also probed if they had earned any graduate or other advanced degrees or were currently enrolled as a student. If respondents answered yes to either, we classified their degrees by type (e.g., master's, doctorate) and field. Degree type and field lists were based on those in the NSF SESTAT[3] and other degrees unique to our partner schools.

Current work characteristic measures

We analyzed several measures related to respondents' current work. Respondents were asked to situate their work in one of seventeen industry sectors (Table 4) and five organizational sectors (Table 5). Sector lists were based on those in the 2009 Stanford University Alumni Survey[49].

Table 4. Industry sectors

Agriculture, forestry, fishing and hunting, and mining	Health
Construction	Higher education
Manufacturing	Other educational services
Wholesale or retail trade	Arts, entertainment, recreation, and food services
Transportation, warehousing, or utilities	Other services (except public administration)
Publishing and communications	Public administration (except armed forces)
Finance, insurance, and real estate	Armed forces
Professional and business services	Other (not listed above)
Scientific and technical services	

Table 5. Organizational sectors

Self-employed: own business or professional practice (non-group)
Private for-profit corporation/company/group-practice
Government or other public institution or agency
Private non-profit organization
Other (not listed above)

Number of hours worked per week was asked on the survey as, “How many hours do you work in a typical week,” and measured on a 10-point scale (0, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, and 80+). Number of direct reports was asked as, “In your current and primary employed position … how many people directly report to you,” and measured on a six-point scale (0, 1-2, 3-5, 6-10, 11-24, and 25+). For both numbers of hours worked per week and number of direct reports, respondents were able to mark “not applicable.” These measures were borrowed with permission from Fouad and Singh[42].

Work, position, and identity measures

We queried respondents’ perceptions about their work, current positions, and engineering identities. Respondents rated the importance of twenty competencies in their current work on a five-point scale, from 0=“not important” to 4=“extremely important.” Shown in Table 6, these competencies came from the 2011-2012 ABET Criterion 3 a-k student outcomes[1] and the key attributes listed in the NAE *Engineer of 2020* report[2].

Table 6. ABET and Engineer of 2020 measures

Math [a]	Global/societal context [d]
Science [a]	Economic issues [d]
Planning/conducting experiments [b]	Environmental context [d]
Analytical skills [b]	Life-long learning
Design	Engineering techniques/tools
Teamwork	Creativity
Problem solving	Business knowledge [e]
Professionalism [c]	Management skills [e]
Ethics [c]	Leadership
Communication	Managing uncertainty

Note: Some attributes and outcomes were separated into multiple stems in order to capture individual competencies (see table footnotes below for original sources).
[a] ABET, outcome A: “an ability to apply knowledge of mathematics, science, and engineering”.
[b] ABET, outcome B: “an ability to design and conduct experiments, as well as to analyze and interpret data”.
[c] ABET, outcome F: “an understanding of professional and ethical responsibility”.
[d] ABET, outcome H: “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”.
[e] *Engineer of 2020*, “business and management skills”.

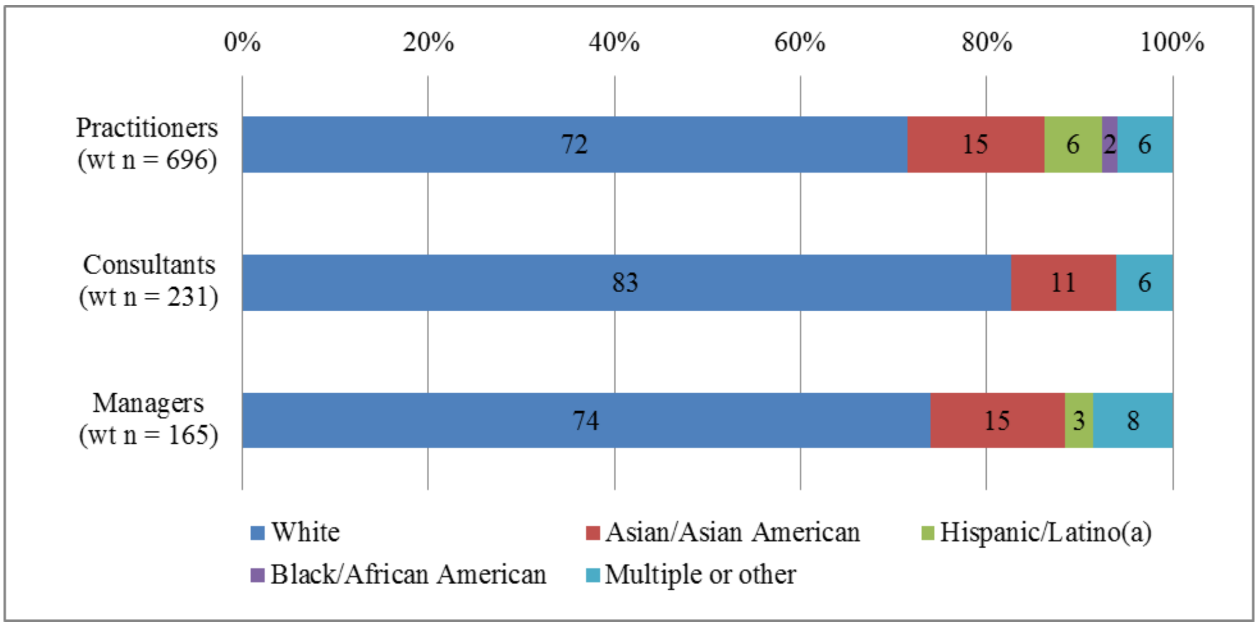
Respondents were asked to describe their current position as either an engineering position or a non-engineering position, and to answer whether they currently identify themselves as an engineer (yes/no/not sure). These measures were based in our Academic Pathways Study[16-18] and Engineering Pathways Study work[43]. In a question adapted from the NSF SESTAT surveys[3], they also indicated how they saw their current position as related to their undergraduate engineering education.

Results

Comparison of demographic measures

We compared engineering practitioners, engineering consultants, and engineering managers on key demographic measures. Women represented 16 percent of both practitioners and consultants, and 26 percent of managers, a difference not found to be statistically significant[ii]. The majority of graduates in each group were White (Figure 3). By contrast, few to no graduates in each group were Hispanic/Latino or Black/African American. These patterns are similar to those found among early career engineering graduates employed in engineering nationally[52].

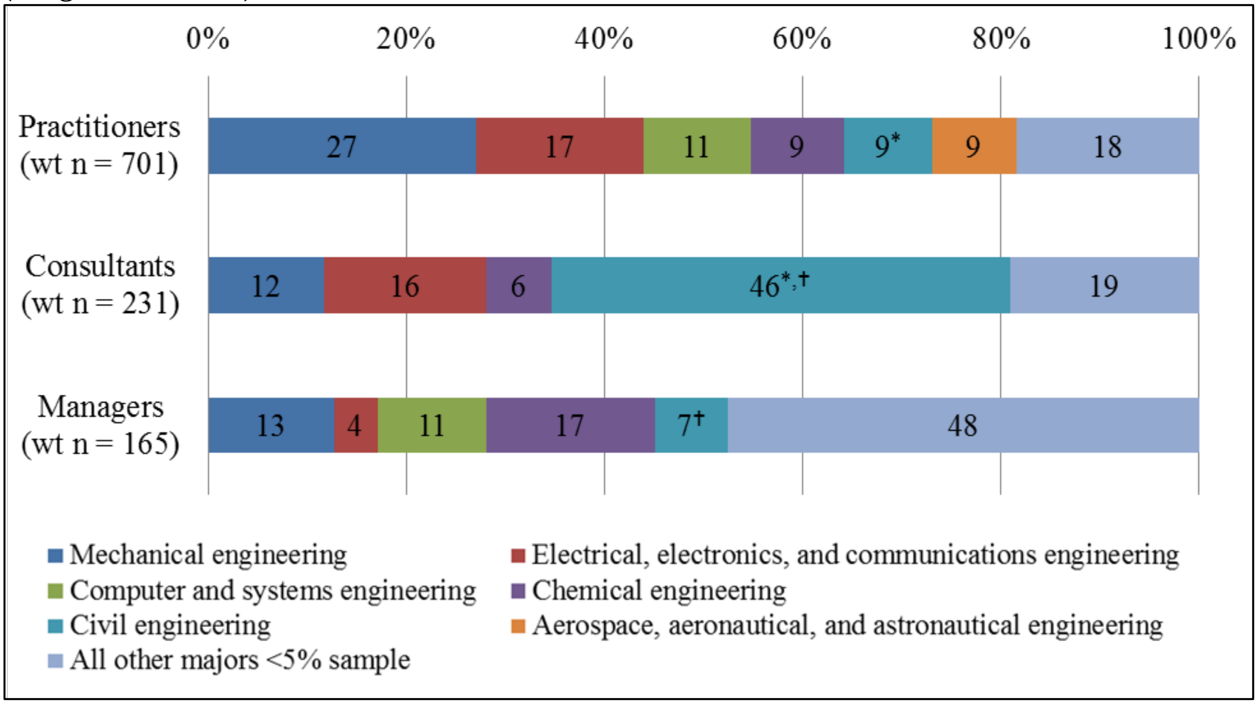
Figure 3. Race/ethnicity for respondents in each engineering sub-occupation (weighted n=1,092).



Note: Pearson's chi-square tests were performed to test the association between sub-occupation rates and race/ethnicity. Due to small sample sizes, these tests were conducted among Whites and Asian/Asian Americans only. Differences were not found to be statistically significant. Percentages may not total 100% due to rounding.

As illustrated in Figure 4, engineering practitioners were mostly likely to be mechanical engineering degree earners (25%), followed by electrical engineering degree earners (17%). In contrast, nearly 50 percent of consultants had earned their undergraduate degrees in civil engineering, and managers were most likely to come from "all other" engineering majors. (Note that although a fifth of the managers in the "all other" major category graduated with an industrial engineering degree, this proportion is less than the proportion of all engineering managers who earned chemical engineering degrees). Differences were statistically significant with respect to the proportions of each group earning civil engineering degrees. Although the overall test reached significance for mechanical engineering degrees, pairwise *post hoc* comparisons did not.

Figure 4. Undergraduate engineering major for respondents in each engineering sub-occupation (weighted n=1,096).



Note: Pearson's chi-square tests and *post hoc* Fisher's exact tests were performed to test the association between sub-occupation rates and undergraduate engineering major. Due to small sample sizes, these tests were conducted among the top three majors only: civil engineering, electrical, electronics, and communications engineering, and mechanical engineering. Percentages may not total 100% due to rounding.

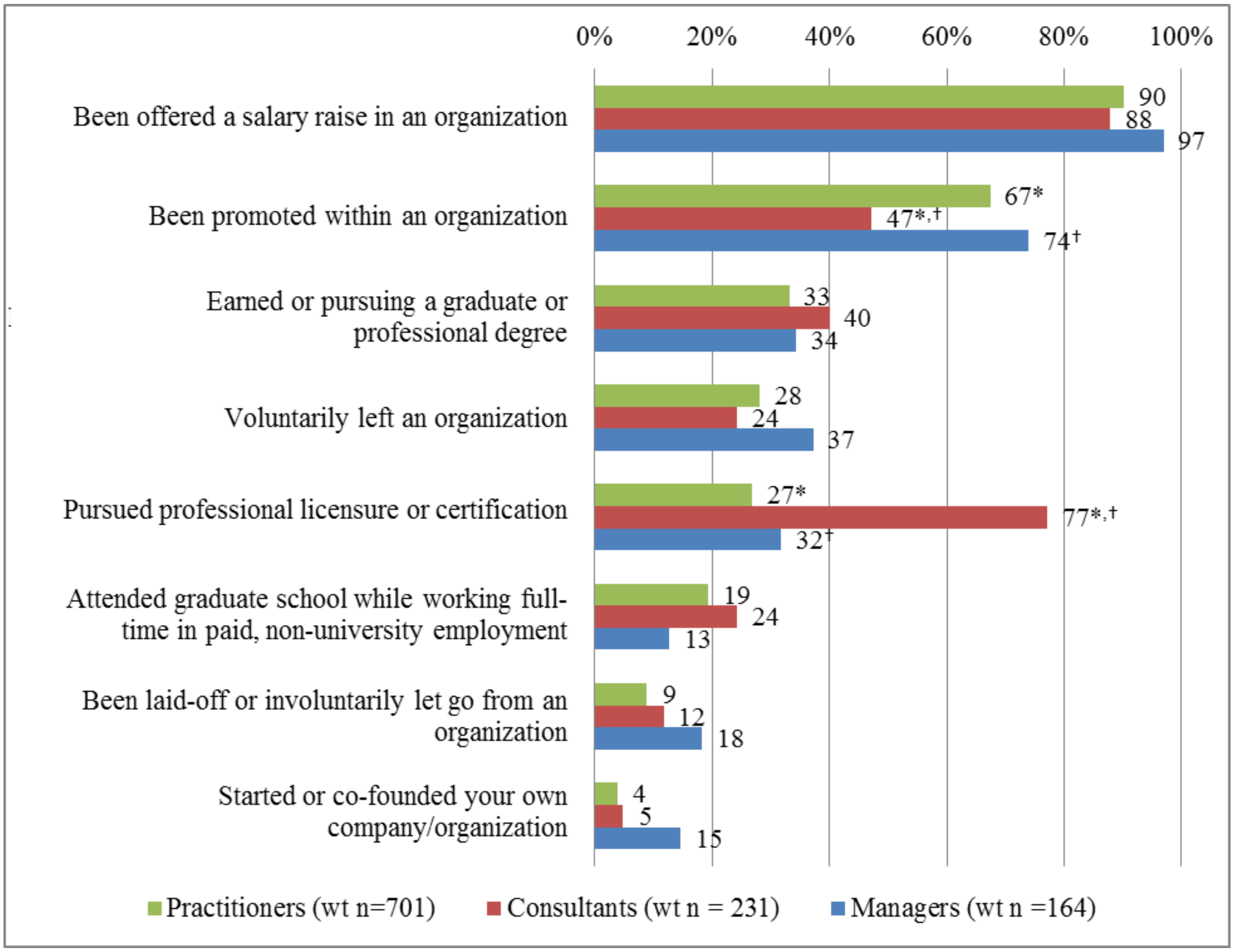
* Significant difference between practitioners and consultants.

† Significant difference between consultants and managers.

Comparison of career milestone and experience measures

Differences between sub-occupations were found in graduates' post-graduation career milestones and experiences (Figure 5). Significantly more consultants reported having pursued professional licensure or certification after earning their bachelor's degree than practitioners or managers did. Consultants were also the least likely group to have been promoted within an organization.

Figure 5. Career milestone and experience items and the percentage of respondents in each engineering sub-occupation who selected them (weighted n=1,096).



Note: Pearson's chi-square tests and *post hoc* Fisher's exact tests were performed to test the association between sub-occupation rates and each career milestone/experience. Due to small sample sizes, these tests were conducted among items (from top to bottom) 1, 3-5, and 7-8 only.
* Significant difference between practitioners and consultants.
† Significant difference between consultants and managers.

Looking at graduates' academic attainment, consultants were slightly more likely to have earned or to be pursuing a graduate (e.g., master's, doctorate) or other advanced degree compared to practitioners or managers (Figure 5, item 3), but this difference was not significant. Figure 6 and Figure 7 show the distribution of graduates by highest degree earned and highest degree pursuing. As shown, most graduates had not yet pursued additional degrees beyond the bachelor's in engineering. Of those who had, the majority pursued master's degrees in engineering, with some pursuing master's degrees in computer science and business administration.

Figure 6. Highest degree earned for respondents in each engineering sub-occupation (weighted n=1,097).

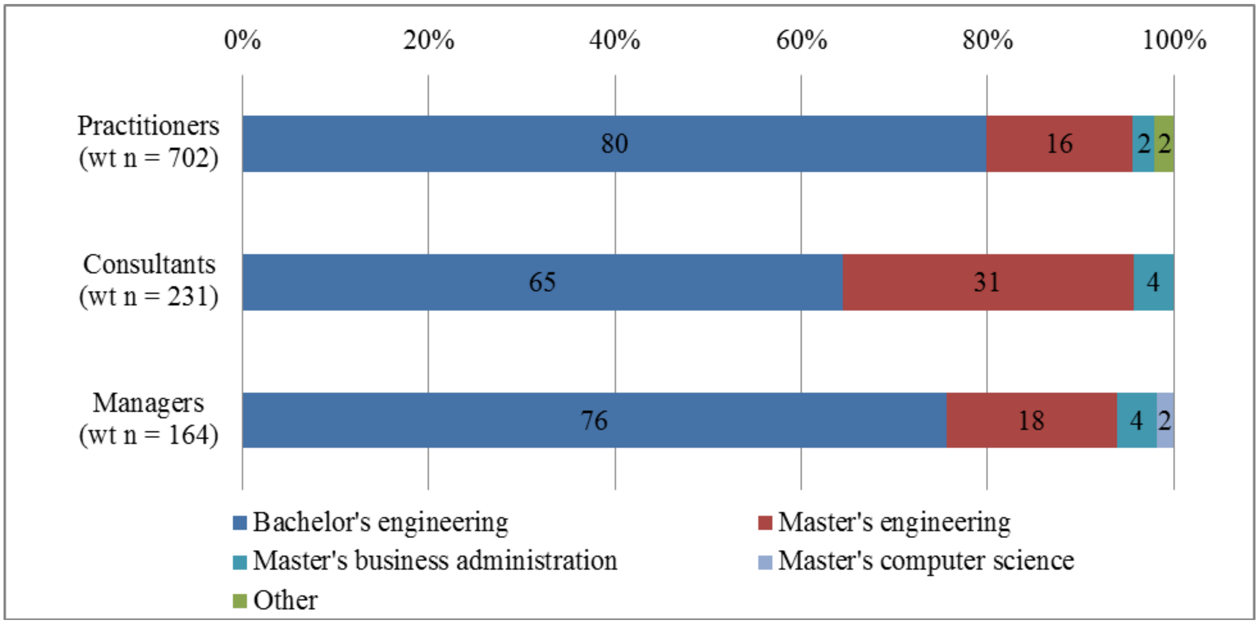
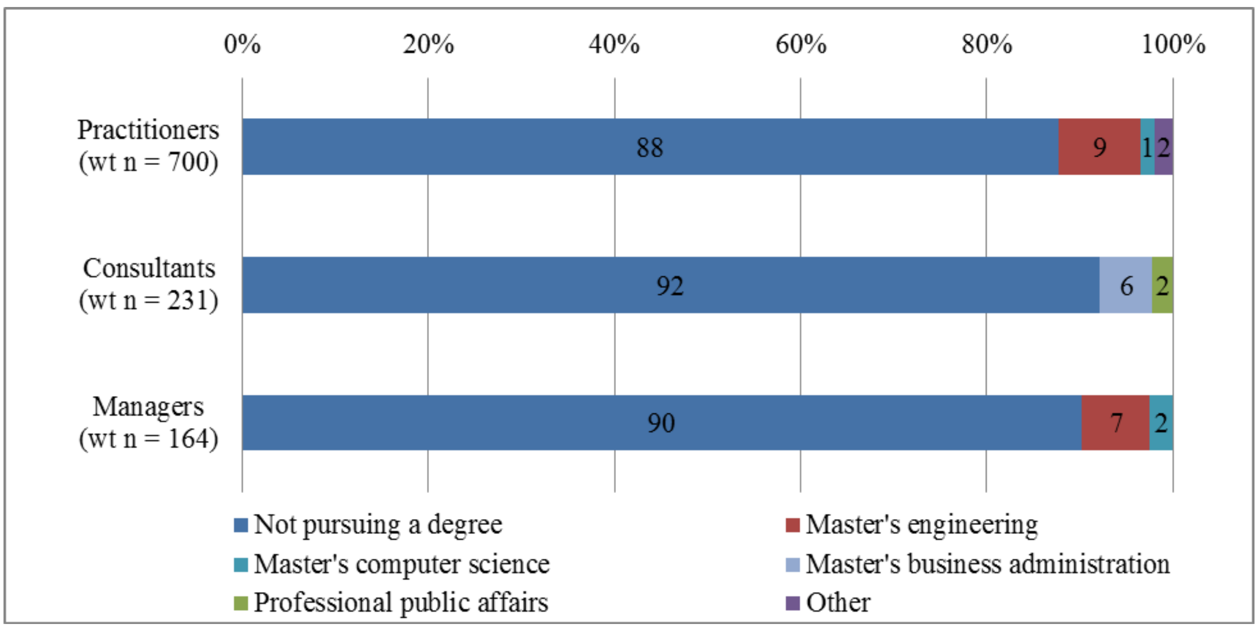


Figure 7. Highest degree currently pursuing for respondents in each engineering sub-occupation (weighted n=1,095).

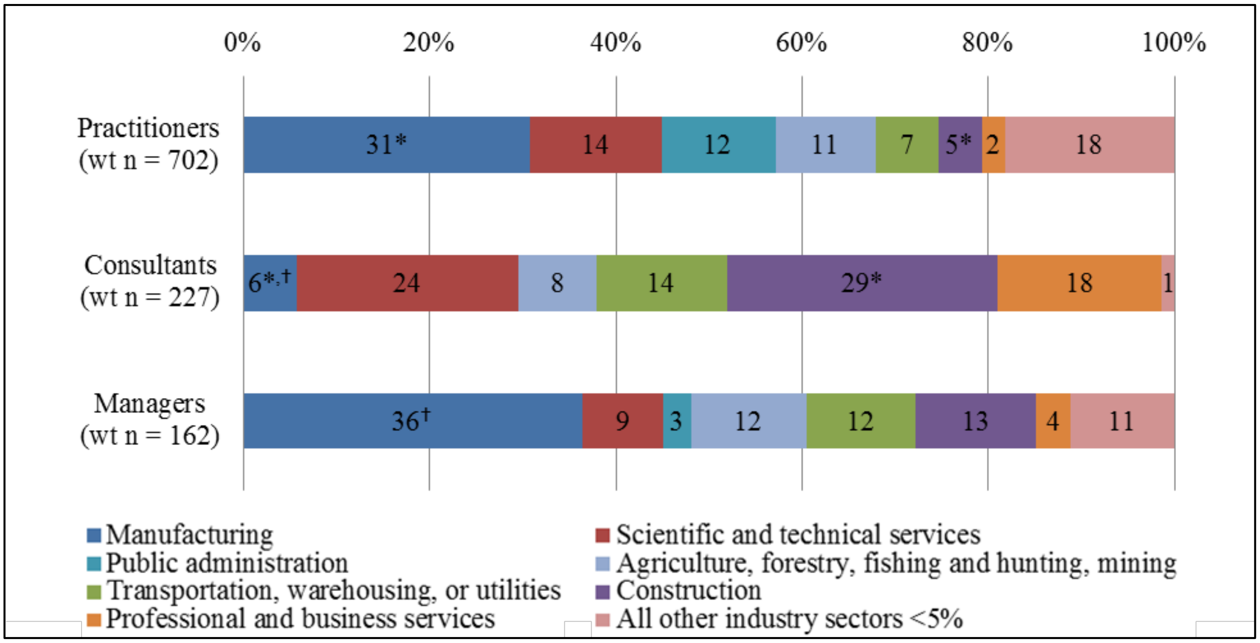


Note: Percentages may not total 100% due to rounding.

Comparison of current work characteristic measures

Tests of industry sector revealed that consultants were more likely than practitioners to be working in construction, but less likely than both practitioners and managers to be working in manufacturing (Figure 8). They were also the most likely group to be working in the private, for-profit sector (95% compared to 88% of practitioners and 84% of managers), although this difference was not statistically different from zero[iii]. None of our survey respondents indicated self-employment.

Figure 8. Industry sector for respondents in each engineering sub-occupation (weighted n=1,091).



Note: Pearson's chi-square tests and *post hoc* Fisher's exact tests were performed to test the association between sub-occupation rates and industry sector. Due to small sample sizes, these tests were conducted among the top four industry sectors only: agriculture, forestry, fishing and hunting, and mining, construction, manufacturing, and scientific and technical services.

* Significant difference between practitioners and consultants.

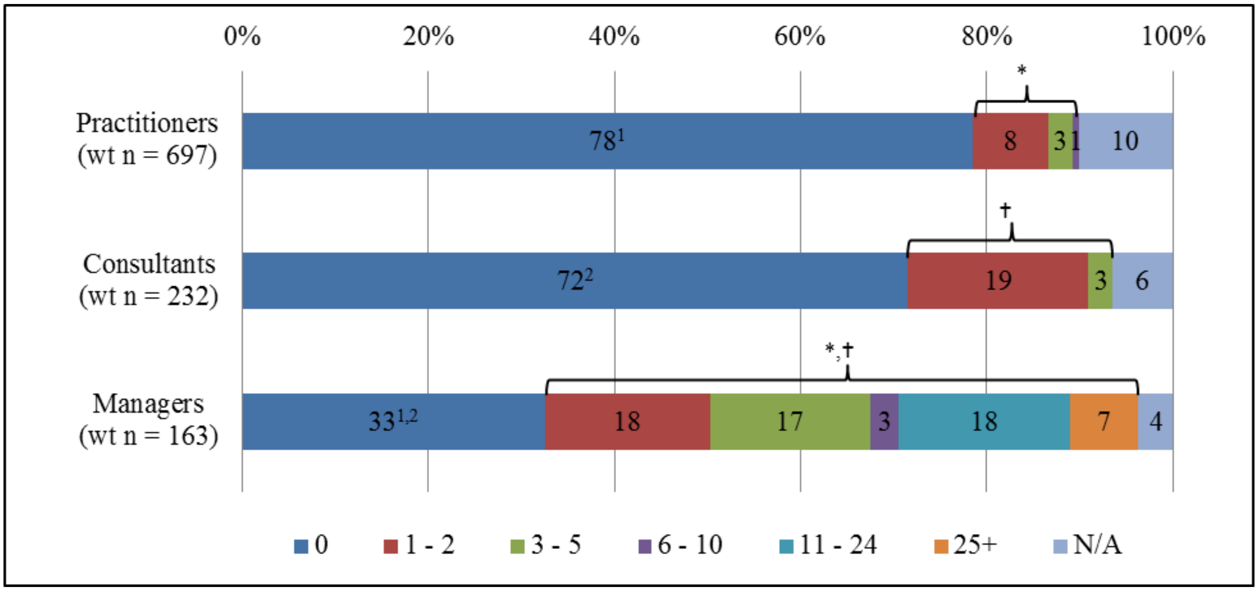
† Significant difference between consultants and managers.

Managers indicated having significantly more direct reports (Figure 9) than practitioners or consultants did. Whereas two-thirds of managers had at least one direct report, roughly three-quarters of the other two groups had none. Managers also tended more than practitioners and consultants to work 50 or more hours per week, while consultants were most likely to work less than 40 hours per week (Figure 10). Based on the unweighted responses to another question, however, only four practitioners and five consultants reported working part-time.

Comparison of perception measures

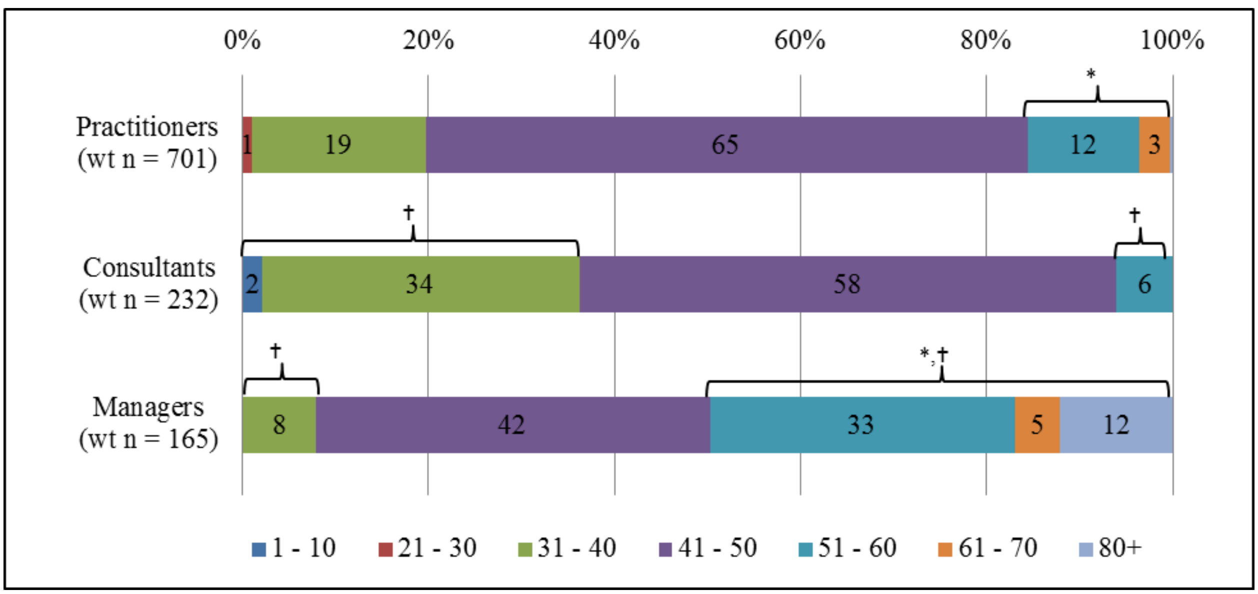
From Figure 11, we see that most graduates identified non-technical competencies including communication, teamwork, professionalism, managing uncertainty, ethics, and lifelong learning as "very" to "extremely" important to their work. They also bestowed these ratings on problem solving, analytical skills, and the use of engineering techniques and tools, whereas knowledge of math, science, and different contexts (i.e., environmental, economic, social, and global) appear less important.

Figure 9. Number of direct reports for respondents in each engineering sub-occupation (weighted n=1,092).



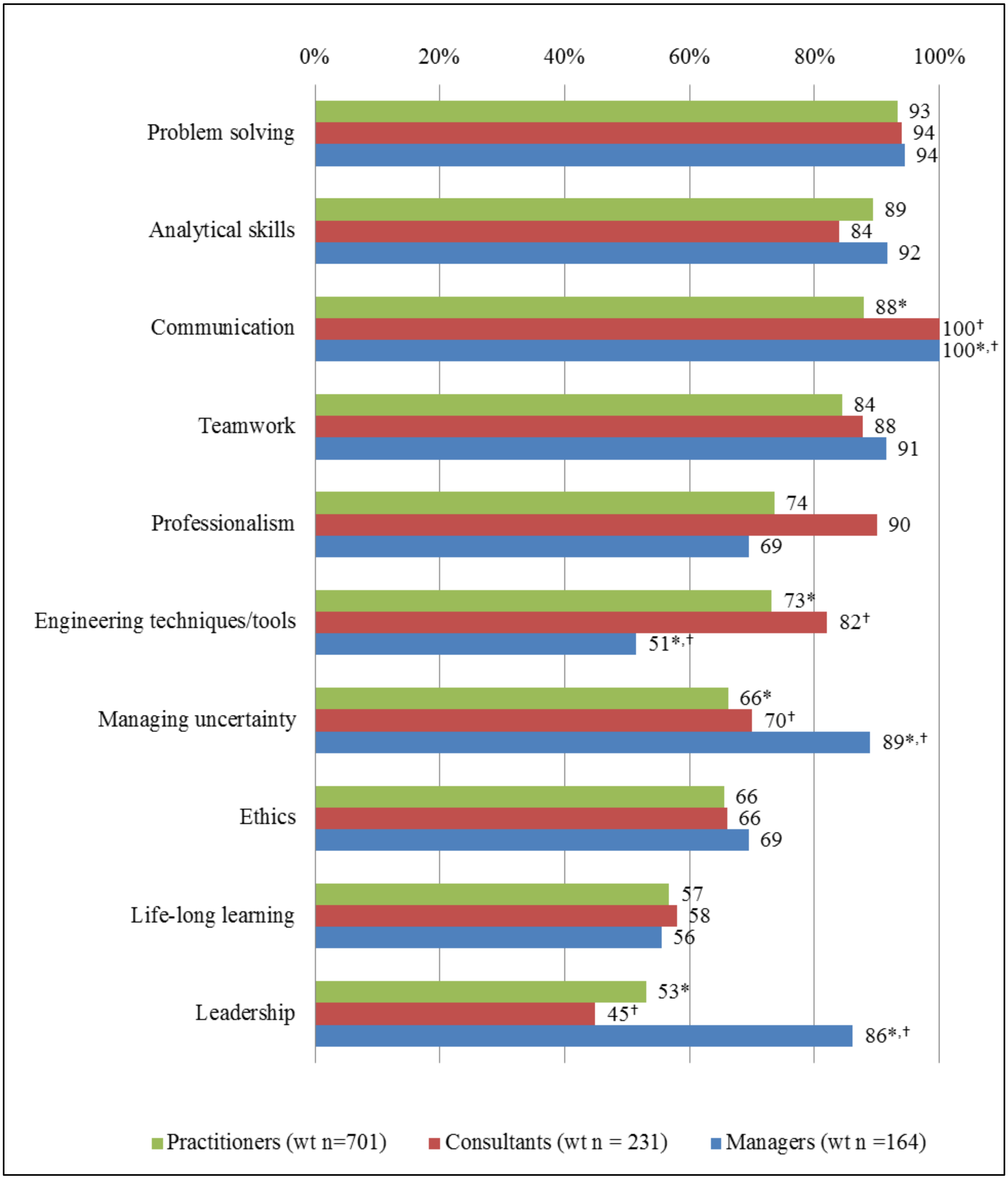
Note: For tests of significance, this variable was recoded into two categories, 0 and 1+, due to small sample sizes. Pearson's chi-square tests and *post hoc* Fisher's exact tests were performed to test the association between sub-occupation rates and number of direct reports.
* Significant difference between practitioners and managers.
† Significant difference between consultants and managers.

Figure 10. Number of hours worked per week for respondents in each engineering sub-occupation (weighted n=1,098).



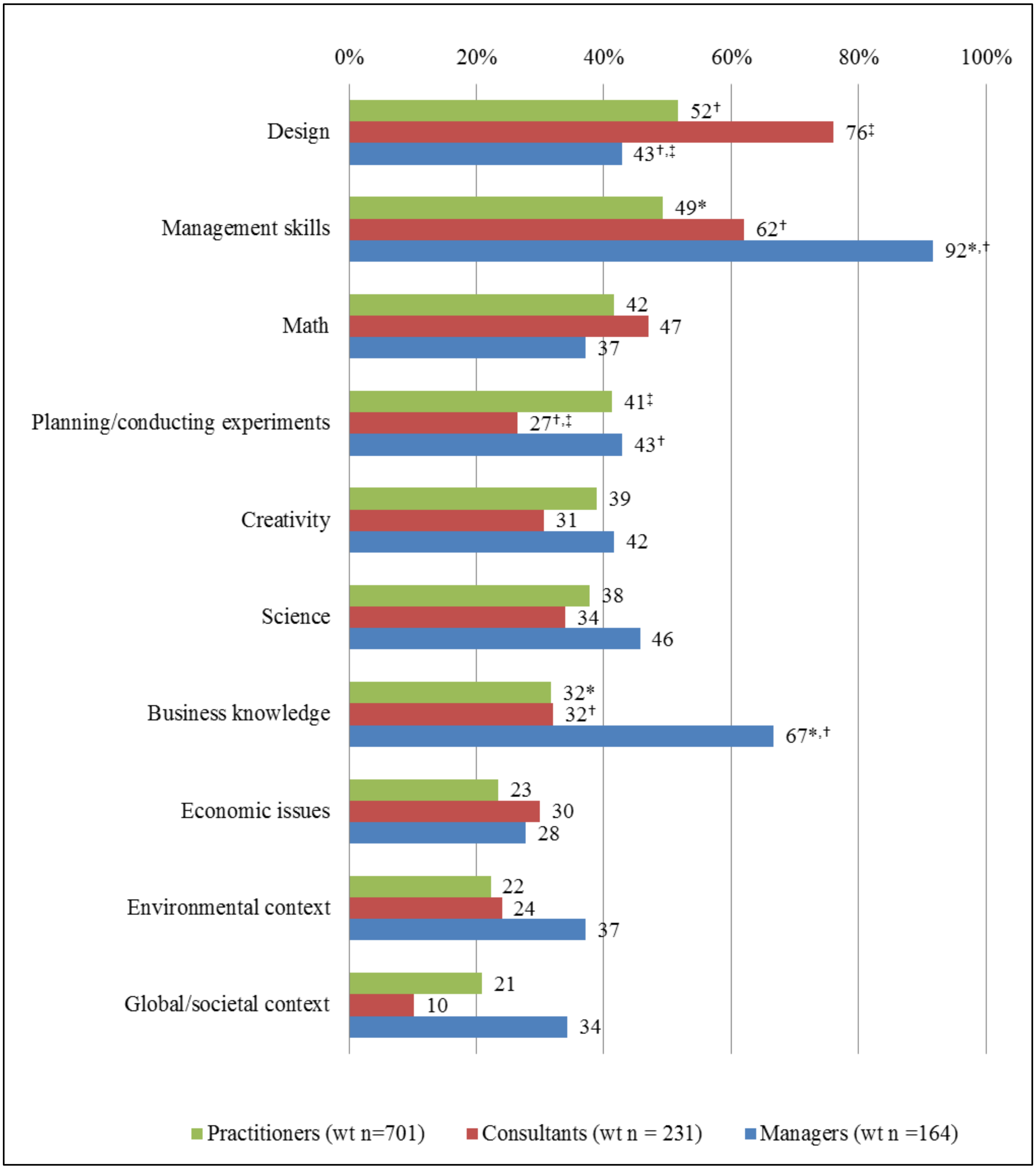
Note: For tests of significance, this variable was recoded into three categories, 1-40, 41-50, and 50+, due to small sample sizes. Pearson's chi-square tests and *post hoc* Fisher's exact tests were performed to test the association between sub-occupation rates and number of hours worked per week.
* Significant difference between practitioners and managers.
† Significant difference between consultants and managers.

Figure 11. Competency items and the percentage of respondents in each engineering sub-occupation who marked "very" to "extremely" important to their work (weighted n=1,081).



Note: Kruskal-Wallis tests and *post hoc* Mann-Whitney tests were performed on the full, five-point response scale to test the association between sub-occupation rates and each competency. Only the percentages of responses "very" to "extremely" important are shown to simplify data reporting. Percentages may not total 100% due to rounding.
* Significant difference between practitioners and managers.
† Significant difference between consultants and managers.
‡ Significant difference between practitioners and consultants.

Figure 11, continued. Competency items and the percentage of respondents in each engineering sub-occupation who marked “very” to “extremely” important to their work (weighted n=1,081).



Note: Kruskal-Wallis tests and *post hoc* Mann-Whitney tests were performed on the full, five-point response scale to test the association between sub-occupation rates and each competency. Only the percentages of responses “very” to “extremely” important are shown to simplify data reporting. Percentages may not total 100% due to rounding.

* Significant difference between practitioners and managers.

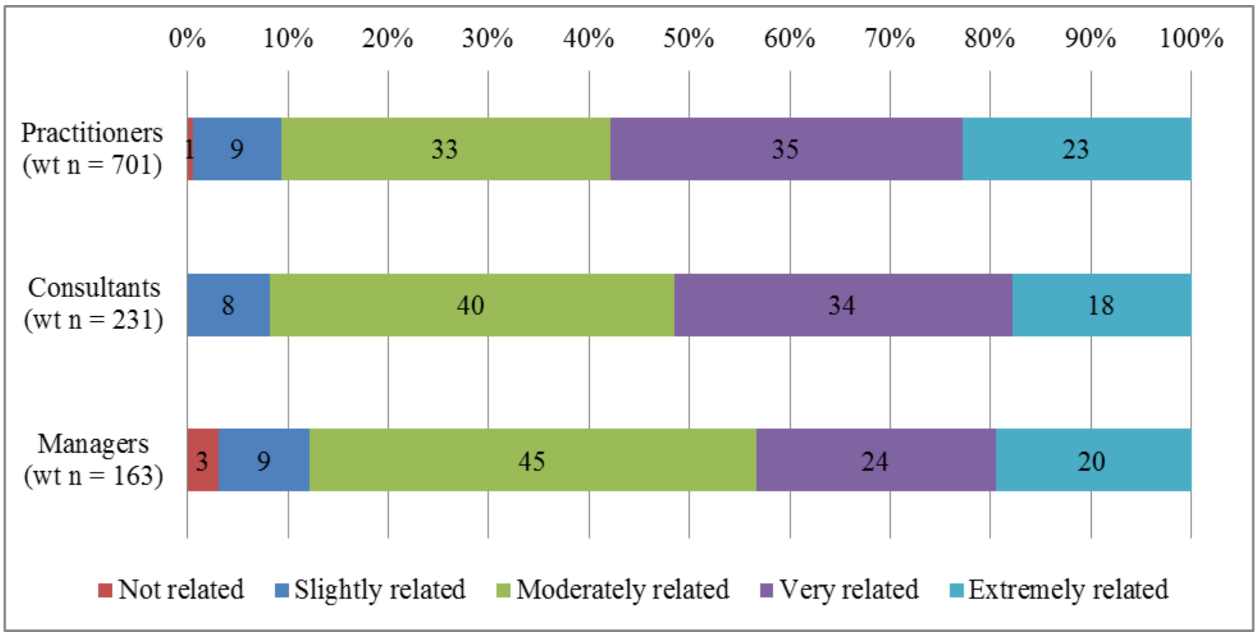
† Significant difference between consultants and managers.

‡ Significant difference between practitioners and consultants.

Compared to practitioners and consultants, managers perceived competencies such as business knowledge, leadership, management skills, and managing uncertainty as significantly more important, and using engineering techniques and tools as significantly less important to their jobs. Consultants, on the other hand, assigned higher scores to design and lower scores to planning and conducting experiments.

Although tests could not be performed due to small sample sizes, we note that twenty percent of managers considered their current position to be non-engineering related, compared to just two percent of practitioners and four percent of consultants. Responses about whether they identified themselves as an engineer followed the same trend. There was no significant difference among the three groups, however, in terms of the perceived relatedness between their current position and undergraduate education (Figure 12).

Figure 12. Relatedness of current position to undergraduate engineering education for respondents in each engineering sub-occupation (weighted n=1,081).



Note: For tests of significance, this variable was recoded into three categories, not to moderately related, very related, and extremely related, due to small sample sizes. Pearson's chi-square tests were performed to test the association between sub-occupation rates and relatedness. Differences were not found to be statistically significant. Percentages may not total 100% due to rounding.

Summary of group differences

Relative to engineering practitioners and consultants, engineering managers tended to come from "all other" engineering majors, followed by chemical engineering. They were also more likely than engineering consultants to work in manufacturing. Among the three groups, engineering managers had the most direct reports, worked the most hours per week, and relied most on non-technical competencies. They saw weaker ties between their current position and identity to engineering, even though they perceived their work as no less related to their engineering education.

Engineering consultants resembled engineering practitioners in the skills and knowledge they thought were important to their work, their level of supervisory responsibility, and the way they saw their current position and identity. Otherwise consultants tended to work fewer hours per week than practitioners or managers did, and their positions required more design work than other competencies such as planning and conducting experiments. Consultants were also distinctive in terms of their backgrounds and post-graduation experiences. They were more than five times as likely as both managers and practitioners to have earned their bachelor's degrees in civil engineering, and more than two times as likely to have pursued professional licensure and work in the construction sector.

Comparisons with non-engineers

The differences above raise the question if engineering consultants and engineering managers should be identified as engineers, or if they more aptly resemble other managers and consultants. To answer this question, we also examined differences between the engineering managers and non-engineering managers (weighted n=77) and between the engineering consultants and non-engineering consultants (weighted n=73) in our sample.

Engineering managers were similar to those who had become non-engineering managers in terms of the kinds of bachelor's degrees they earned and the industries they worked in, their number of direct reports, and number of hours worked per week. They differed significantly in their perceptions of their work, their current positions, and their identities. Engineering managers gave significantly higher importance ratings to design, using engineering techniques and tools, problem solving, science, and communication. They were also more likely to view their current position as an engineering position and to identify with being an engineer (80% of engineering managers, compared with roughly 40% of non-engineering managers, for both). Finally, they were more likely to see their current position as related to their undergraduate education.

Differences between engineering consultants and non-engineering consultants in our sample were even more marked. Engineering consultants were significantly more likely to have earned bachelor's degrees in civil engineering and to have pursued licensure or certification. They also worked significantly fewer hours per week. Ninety-six percent of engineering consultants viewed their current positions and identities as engineering-related, compared to less than a third of non-engineering consultants. Engineering consultants relied significantly more on design, engineering techniques and tools, environmental context, math and science and less on analytical skills, business knowledge, communication, leadership, management skills, problem solving, professionalism and teamwork. Like engineering managers, they were also more likely to see their current position as related to their undergraduate education.

Based on these results, engineering managers and engineering consultants appear more closely related to engineering practitioners than their non-engineering counterparts. Still, our findings demonstrate that graduates in these sub-occupations take on distinctive profiles, with their post-graduation experiences, current work characteristics, and perceptions intersecting in complex ways. The next section contextualizes these profiles in the literature and presents implications of this work for educational research and practice.

Discussion

To certain extents, the profiles of engineering sub-occupations presented in this paper have been documented elsewhere. According to Reese, the average young civil engineer, who represents nearly half of the consultants in our study, "has not bothered to obtain any sort of advanced degree, ... tends to work for general consulting firms, and has obtained a P.E. registration"[53]. Furthermore, the American Society of Civil Engineers has described consulting and construction as typical civil engineering career paths, particularly noting that consulting is design intensive[54] and that advancement within civil engineering is gradual and contingent upon licensure[55]. Engineering managers, on the other hand, are typically promoted rapidly and with little formal management training (e.g., an MBA or equivalent)[56]. First-line engineering managers often work in manufacturing, where there is great demand for line supervision[23]. Thus our findings are consistent with those found by other studies.

Our comparison of sub-occupations also builds on the prior work by revealing potentially important relationships in engineers' perceptions about their work, current positions, and engineering identities. Although each group relied on a mix of technical and non-technical competencies, engineering managers were especially concerned with the interpersonal and administrative aspects of engineering. That they rated communication as higher in importance than even non-engineers speaks to the effort required in their work to successfully navigate both technical and supervisory responsibilities, which some researchers have noted can be difficult for both supervisors and subordinates[11,22]. Managers were also least likely to see their current position as engineering-related or to identify as engineers. Although the exact reason for these dual trends is not apparent, the literature suggests two possible explanations.

The first explanation presumes that engineering managers seek out managerial positions because they feel either a weaker identification with engineering, or alternatively, a stronger orientation towards business and leadership. Ro indicates that this orientation can be developed in educational settings in a variety of ways, from greater attention to professional skills and an emphasis on active and collaborative pedagogies in the classroom, to participation in student organizations[19]. Some graduates may become attuned to the management pathway through their early work experiences or the influence of friends and family. Still others may treat their engineering degree as a stepping stone to managerial opportunities in the first place[57].

In the second explanation, engineering managers' daily work activities influence their perceptions of their current position, which then in turn influences their sense of engineering identity. For all of the emphasis on equipping engineering students with *both* technical and professional skills, several studies have demonstrated a perception among engineers that "real" engineering is synonymous with "technical problem solving"[11,21,23] or with "the hands-on 'nuts and bolts' work"[30]. Tasks such as communication, coordination and helping others are conversely seen as not real engineering work, as they do not utilize the technical skills learned in the undergraduate engineering curriculum[30] nor is there a "tangible individual accomplishment to which to point"[11]. Since most engineering managers are promoted to their positions for their technical expertise[11,56], it seems reasonable that, once in management, they may no longer associate their work with engineering. As Faulkner observed, these engineers' roles as "boundary spanners" can "potentially weaken their membership as 'real' engineers"[30]. At the same time, engineering managers often bring little formal management training to their new roles (recall that more engineering managers earned master's degrees in engineering than earned MBAs) and thus may not fully identify with being managers either. With prior research supporting both possible explanations, more work is needed to better understand the identity development of engineering managers, especially in the early years after graduation.

Recommendations for Further Research

In addition to more work on engineering managers, further research into the pathways of engineering consultants is needed as well. As previously mentioned, engineering consultants in our study more closely resembled engineering practitioners than engineering managers in their work and identity perceptions. This result was expected since entry level engineering consulting work has been known to involve "basic engineering evaluations, computations, and design"[54]. Consultants in our study were also less likely than practitioners or managers to have been promoted, perhaps because consulting firms are small and may not offer as many advancement opportunities as larger corporations might. Four years after graduation, however, many consultants have earned or will soon be earning their professional license. If they stay in consulting, they are expected to choose a professional track which, depending on the track (i.e., technical, management, business), may require more client interaction and project management[54]. It therefore remains to be seen whether engineering consultants in the next stage of their career face the same boundary-spanning challenges that engineering managers do. Longer-term study of engineering consultants could help to answer this question.

The results of this paper also support longitudinal study of engineering graduates in general. Just as entry level engineering consultants will advance in their careers, we anticipate more engineering practitioners to be promoted to first-line or mid-level engineering managers, some engineering managers to become business managers, and members of all three groups to exit engineering altogether. We might also expect increases in the number of graduates earning advanced technical degrees and MBAs. By examining changes in engineers' professional trajectories over time, we can begin to elucidate the needs of engineers at different career stages and the ways that both undergraduate and continuing education can address them.

Lastly, further research is needed to draw out the connections engineering graduate see between their undergraduate education and current work. As shown, the graduates in our study varied little on our measure of relatedness but were left to define what this means for themselves; possible interpretations range from whether they were working in the same engineering field as their major to whether they felt prepared to do their jobs. We note that graduates in all three sub-occupations rated problem solving as most important to their work. Thus another possible interpretation is that problem solving forms the core of all engineering graduates' education and work, and that it is the translation of problem solving into different spaces and positions where we begin to see variation. More work is needed to determine exactly how each group construed "relatedness" so that we may better understand our findings. Likewise, a follow-up round of interviews to those done in the Engineering Pathways Study is recommended, to help understand graduates' responses to this and other self-report measures, namely the identification of their work and selves with engineering. The further exploration of engineering alumni should be extended to a more diverse sampling of institutions and graduation years also.

Implications for Educational Practice

In terms of educational practice, we encourage undergraduate engineering programs to adopt "zero-based career planning"[11], in which all engineering career orientations are recognized as valid. Under this paradigm, programs would help engineering students to develop an understanding of, and appreciation for, engineering as more than just practitioners engaging in technical work. Students would learn about a range of different sub-occupations, the skills and knowledge required by them, the steps for career success and advancement, and the long-term career trajectories possible. They would also receive help mapping these sub-occupations on to their own career goals and interests, thereby enabling more students to see value in engineering.

One way for programs to enact the zero-based career planning model is by offering courses that help students to learn about different career paths (e.g., engineering management). In programs already over-burdened with high curricular demands, faculty can redesign projects and case studies to showcase what it is like to pursue various career paths, such as having students develop a product for a real or imagined client. Engineering programs can facilitate exposure to diverse careers through experiences outside of the classroom as well. They can work with the student chapters of professional engineering societies on campus to provide skills training, license exam workshops, guest speakers, and career panels. They can encourage students to pursue research and internship experiences. Engineering faculty and staff should also be prepared to discuss various employment opportunities with students as part of career counseling and advising as well. Through experiences and encounters such as these, students can begin to understand the multifaceted nature of engineering and to identify specific interests. Thus it is important that they also be given time, resources, and guidance to reflect on and research how what they are learning could translate into different career options.

Industry representatives can play a key role in all of these activities by facilitating the interaction of engineering students with engineering professionals. On-campus, they can deliver guest lectures, provide advice and mentoring, and serve as adjunct faculty. Moreover, they can coordinate field trips, sponsor projects, provide content for assignments, and create apprenticeships. Industry representatives also play a crucial role in providing feedback to engineering programs about the quality of the graduates they are producing, and in helping both faculty and students understand how skills and knowledge learned in the classroom translate into real-life engineering work (e.g., using problem solving skills in engineering management to solve business issues, rather than just technical ones).

For their part, students should be encouraged to have a stake in their own professional development. They can develop a long-term vision and short-term plan to achieve their ultimate career goals. They can seek out mentors who have had career paths similar to the one they desire, in addition to pursuing informational interviews with others whose paths they would like to learn more about, such as engineering alumni. By making known the requirements of different engineering paths, and the tools to find out more about them, engineering programs and industry representatives can help students to take better control of their career futures.

Acknowledgments

The authors would like to acknowledge support for several of the authors from the Office of the Vice Provost for Undergraduate Education (VPUE) and the Office of the Vice Provost for Graduate Education (VPGE) at Stanford University. We also wish to thank the entire Engineering Pathways Study research team, our alumni association partners at the four PEARS institutions, and the study participants. This work was supported by the National Science Foundation as a collaborative research grant (NSF-DUE-1020678, 1021893, 1022024, 1022090, and 1022644). Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF.

Bibliography

1. ABET. (2012). *Criteria for accrediting engineering programs.* Accessed January 2, 2013, at www.abet.org/uploadedFiles/Accreditation/Accreditation_Process/Accreditation_Documents/Current/eac-criteria-2012-2013.pdf.
2. National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century.* Washington, D.C.: National Academies Press.
3. National Science Foundation, Science and Engineering Statistics Data System (SESTAT). (2012). SESTAT variable information. Accessed January 2, 2012, at www.nsf.gov/statistics/sestat/variableinfo.cfm.
4. United States Department of Labor, Bureau of Labor Statistics. (2000). *2000 Standard Occupational Classification System.* Accessed January 2, 2013, at: www.bls.gov/soc/socguide.htm.
5. Jamieson, L., & Lohmann, J. (2009). *Creating a culture for scholarly and systematic innovation in engineering education. Phase 1 report.* Washington, D.C.: American Society for Engineering Education.
6. Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2008). *Educating engineers: Designing for the future of the field.* San Francisco, CA: Jossey-Bass.
7. American Society of Civil Engineers. (2008). *Civil engineering body of knowledge for the twenty-first century: Preparing the civil engineer for the future (2nd ed.).* Reston, VA: American Society of Civil Engineers.
8. Boeing Company. (2009). Desired attributes of an engineer. Accessed January 2, 2013, at www.boeing.com/educationrelations/atributes.html.
9. Duderstadt, J. (2008). *Engineering for a changing world: A roadmap to the future of engineering practice, research, and education.* Ann Arbor, MI: University of Michigan.
10. National Academy of Engineering. (2008). *Grand challenges in engineering.* Accessed January 2, 2013, at www.engineeringchallenges.org.
11. Perlow, L., & Bailyn, L. (1997). The senseless submergence of difference: Engineers, their work, and their careers. In: Eds. S. R. Barley & J. E. Orr, *Between craft and science: Technical work in the United States.* Ithaca, NY: Cornell University Press, pp. 230-244.
12. ABET. (2012). *Why accreditation matters.* Accessed January 2, 2013, at www.abet.org/why-accreditation-matters/.
13. Lattuca, L. R., Terenzini, P., & Volkwein, J. F. (2006). *A study of the impact of EC2020, Full Report.* Washington, D.C.: ABET.
14. Passow, H. J. (2012). Which ABET competencies do engineering graduates find most important in their work? *Journal of Engineering Education, 101*(1), 95-118.
15. Knight, D. B. (2012, June). *In search of the Engineers of 2020: An outcomes-based typology of engineering undergraduates.* Paper presented at the annual American Society for Engineering Education Conference, San Antonio, TX.
16. Sheppard, S. D., Gilmartin, S., Chen, H. L., Donaldson, K., Lichtenstein, G.., Eris, O., 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 for Engineering Education.

17. Lichtenstein, G., Loshbaugh, H. G., Claar, B., Chen, H. L., Jackson, K., & Sheppard, S. D. (2009). An engineering major does not (necessarily) an engineer make: Career decision-making among undergraduate engineering majors. *Journal of Engineering Education, 98*(3), 227-234.
18. Matusovich, H.M., Streveler, R., Miller, R.L., & Olds, B.A. (2009, June). *I'm graduating this year! So what IS an engineer anyway?* In Proceedings of the American Society for Engineering Education Annual Conference, Austin, TX.
19. Ro, H. K. (2011). *An investigation of engineering students' post-graduation plans inside or outside of engineering.* Ph. D. dissertation. University Park, PA: The Pennsylvania State University.
20. Bucciarelli, L. L., & Kuhn, S. (1997). Engineering education and engineering practice: Improving the fit. In: Eds. S. R. Barley & J. E. Orr, *Between craft and science: Technical work in the United States.* Ithaca, NY: Cornell University Press, pp. 210-229.
21. Anderson, K. J. B., Courter, S. S., McGlamery, T., Nathans-Kelly, T. M., & Nicometo, C. G. (2010). Understanding engineering work and identity: A cross-case analysis of engineers within six firms. *Engineering Studies*, 2(3), 153-174.
22. Brunhaver, S., Korte, R. F., Lande, M., & Sheppard, S. D. (2010, June). *Supports and barriers that recent engineering graduates experience in the workplace.* In Proceedings of the American Society for Engineering Education Annual Conference, Louisville, KY.
23. Brunhaver, S. R., Korte, R. F., Barley, S. R., & Sheppard, S. D. (Forthcoming). Bridging the gaps between engineering education and practice. In: Eds. R. Freeman & H. Salzman, *U.S. Engineering in the Global Economy.* Cambridge, MA: National Bureau of Economics Research.
24. Dunnette, M. D. (1957). Vocational interest differences among engineers employed in different functions. *Journal of Applied Psychology, 41*(5), 273-278.
25. Dunnette, M. D., & England, G. W. (1957). A checklist for differentiating engineering jobs. *Personnel Psychology, 10*(2), 191-198.
26. Kirkpatrick, J. J. (1956). Validation of a test battery for the selection and placement of engineers. *Personnel Psychology, 9*(2), 211-227.
27. Kulberg, G. E., & Owens, W. A. (1960). Some life history antecedents of engineering interests. *Journal of Educational Psychology, 51*(1), 26-31.
28. Webster, E. C., Winn, A., & Oliver, J. A. (1951). Selection tests for engineers: Some preliminary findings. *Personnel Psychology, 4*(4), 346-362.
29. Brown, J. S., Grant, C. W., & Patton, M. J., (1981). A CPI comparison of engineers and managers. *Journal of Vocational Behavior, 18*(3), 255-264.
30. Faulkner, W. (2007). "Nuts and bolts and people": Gender-troubled engineering identities. *Social Studies of Science, 37*(3), 331-356.
31. Klimoski, R. J. (1973). A biographical data analysis of career patterns in engineering. *Journal of Vocational Behavior, 3*(1), 103-113.
32. Kopelman, R. E. (1977). Psychological stages of careers in engineering: An expectancy theory taxonomy. *Journal of Vocational Behavior, 10*(3), 270-286.
33. Sedge, S. K. (1985). A comparison of engineers pursuing alternate career paths. *Journal of Vocational Behavior, 27*(1), 56-70.
34. Sheppard, S. D., Matusovich, H. M., Atman, C. J., Streveler, R., & Miller, R. (2011, October). *Work in progress: Engineering Pathways Study: The college-career transition.* In Proceedings of the Annual Frontiers in Education Conference, Rapid City, SD.
35. Chen, H. L., Grau, M. M., Brunhaver, S. R., Gilmartin, S. K., Sheppard, S. D., & Warner, M. (2012, June). *Designing the Pathways of Engineering Alumni Research Survey (PEARS).* In Proceedings of the American Society for Engineering Education Annual Conference, San Antonio, TX.
36. Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior,* 45(1), 79-122.
37. Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models. *Journal of Counseling Psychology, 50*(4), 458-465.
38. Lent, R. W., Sheu, H. B., Singley, D., Schmidt, J. A., Schmidt, L. C., & Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior, 73*(2), 328-335.
39. Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., Wilkins, G., Schmidt, L. C., Lyons, H., & Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering:

Utility for women and students at historically black universities. *Journal of Counseling Psychology, 52*(1), 84-92.

40. Schaefers, K. G., Epperson, D. L., & Nauta, M. M. (1997). Women's career development: Can theoretically derived variables predict persistence in engineering majors? *Journal of Counseling Psychology, 44*(2), 173-183.
41. Trenor, J. M., Yu, S. L., Waight, C. L., Zerda, K. S., & Ting Ling, S. H. A. (2008). The relations of ethnicity to female engineering students' educational experiences and college and career plans in an ethnically diverse learning environment. *Journal of Engineering Education*, *97*(4), 449-465.
42. Fouad, N. A., & Singh, R. (2011). *Stemming the tide: Why women leave engineering.* The University of Wisconsin-Milwaukee.
43. Matusovich, H., Brunhaver, S., Kilgore, D., & Babcock, A. (Unpublished). *Engineering Pathways Study: How qualitative findings illuminate understanding of the college-career transition.* Working paper, available by request.
44. Winters, K. E. (2012). *Career goals and actions of early career engineering graduates.* Ph. D. dissertation. Blacksburg, VA: Virginia Polytechnic Institute and State University.
45. Winters, K., Matusovich, H. M., & Brunhaver, S. (2012, April). *The impacts of economic decline on career decision making among early career engineers.* Paper presented at the American Educational Research Association, Vancouver, BC, Canada.
46. Katchadourian, H.A., & Boli, J. (1985). *Careerism and intellectualism among college students.* San Francisco, CA: Jossey-Bass Publishers.
47. Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., Wilkins, G., Schmidt, L. C., Lyons, H., & Treistman, D. (2005). *Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically Black universities.* Journal of Counseling Psychology, 52(1), 84-92.
48. Simard, C., Henderson, A.D., Gilmartin, S.K., Schiebinger, L., & Whitney, T. (2008). *Climbing the technical ladder: Obstacles and solutions for mid-level women in technology.* Stanford, CA: Michelle R. Clayman Institute for Gender Research, Stanford University.
49. Stanford University. (2009). *2009 Stanford University Alumni Survey.* Accessed January 2, 2013, at www.stanford.edu/dept/pres-provost/irds/ir/survey_research/Alum2009.pdf.
50. Atman, C. J., Sheppard, S. D., Turns, J., Adams, R. S., Fleming, L. N., Stevens, R., Streveler, R. A., Smith, K. A., Miller, R. L., Leifer, L. J., Yasuhara, K.,, & Lund, D. (2010). *Enabling engineering student success: The final report for the Center for the Advancement of Engineering Education.* San Rafael, CA: Morgan and Claypool Publishers.
51. Burton, L., & Parker, L. (1998). Intersections of engineering and management: What do the data show. In Proceedings of the American Society for Engineering Education Annual Conference, Seattle, WA.
52. National Science Foundation, National Center for Science and Engineering Statistics. (2012). *Characteristics of recent science and engineering graduates: 2008. Detailed statistical tables NSF 12-328.* Arlington, VA. Accessed January 2, 2013, at: www.nsf.gov/statistics/nsf12328.
53. Reese, C. (2003). Employment history survey of ASCE's younger members. *Leadership and Management in Engineering, 3*(1), 33-53.
54. American Society of Civil Engineers. (2011). *Career paths in civil engineering.* Accessed January 2, 2013, at www.asce.org/uploadedFiles/Leadership_Resources/Leadership_Tools/Career%20Path%20Brochure2011_WEB.pdf.
55. American Society of Civil Engineers. (2010). *Career paths in civil engineering.* Accessed January 2, 2013, at www.asce.org/uploadedFiles/Leadership_Training_-_New/careerpathfinal.pdf.
56. Ryan, P., Lye, L., & Hsiao, A. (2011, June). *When engineers become managers: Learning from current engineering managers to advance engineering management education.* In Proceedings of the Annual Canadian Engineering Education Association Conference, St. John's, Newfoundland, Canada.
57. Rynes, S. L. (1987). Career transitions from engineering to management: Are they predictable among students? *Journal of Vocational Behavior, 30*(2), 138-154.

[i] Individuals who reached the last question in the survey are classified as providing a complete response, whether they completed the survey fully or partially. The weighted distribution of these individuals was comparable to that of the respondent sample. Note that weights adjust for gender and major only.

[ii] Statistical significance was tested using a Pearson's chi-square test, with weighted n=1,097.
[iii] Statistical significance was tested using a Pearson's chi-square test, with weighted n=1,073. Due to small sample sizes, this test was conducted among graduates working in the private, for-profit sector only.