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Comparing Disparate Outcome Measures for Better Understanding of Engineering Graduates

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Abstract

Despite a strong emphasis on increasing post-graduation engineering retention, few research studies have examined what it actually means to stay in or leave engineering work. This study addresses this limitation using a weighted survey sample of roughly two thousand early career engineering graduates. The research is broadly situated in social cognitive career theory and draws data from the Pathways of Engineering Alumni Research Survey (PEARS), which was a part of the National Science Foundation (NSF) funded Engineering Pathways Study (EPS). Analyses for this study followed a two-step process. First we categorized the engineering graduates into seven occupational groups, and then we compared these seven groups along six other measures of doing engineering work. Four years after graduation, graduates employed in engineering and computer-related occupations tended to identify themselves, their current position, and future plans as engineering-related, while graduates employed in the professions and other non-engineering occupations did not. Additionally, graduates working in fields such as informational technology, business, and the military tended not to perceive themselves as working in engineering; nonetheless, many of these graduates self-identified as an engineer and had plans to pursue engineering work in the future. Our findings demonstrate future research directions for the study of what it means to do engineering work. They also highlight a need for improved career preparation, counseling, and development among early career engineering graduates and students.

Introduction

Since a student earning an engineering bachelor's degree no longer presupposes that he or she will pursue an engineering job,[1] finding ways to increase post-graduation engineering retention has been a priority in engineering education research. A common theme to these studies has been the investigation of individual, programmatic, and contextual factors as they relate to students' and graduates' career choices. A common limitation is that what it means to do or not do engineering work is often left undefined. Several studies ask participants if they are currently working or plan to work in engineering, but participants are left to define engineering for themselves[2-9] even amid evidence that some may not know what it means.[10] Other studies use measures such as perceived degree-job relatedness as a proxy for engineering retention,[11-14] but the fit between this measure and engineers' actual work has been found poor.[15]

In light of these issues, many researchers have defined engineering retention as simply the number of engineering graduates who report being employed in an engineering occupation.[16-21] By this measure, as of 2008, an estimated 1.2 million out of 2.5 million individuals with engineering as their highest degree were retained in engineering.[22] Nonetheless, an obvious limitation of counting engineers in this way is that, unlike using degree-job relatedness, "it will not capture individuals using S&E knowledge, sometimes extensively, under [other] occupational titles".[21] In other words, defining engineering based on occupational classification does not capture the full range of career paths that engineers take.[14,23] Without this understanding, engineering programs are ill-equipped to prepare their students for the future.[24-26]

Our work begins to address these questions by examining several possible definitions of engineering to determine what could be learned about how engineering graduates see their work as pursuing or not pursuing engineering. We accomplish this goal through an exploratory analysis using data from the Pathways of Engineering Alumni Research Survey (PEARS), which was a part of the NSF-funded Engineering Pathways Study (EPS). [27-28] The EPS project investigated the career pathways and preparation of graduates four years since earning their bachelor's degrees in engineering. We focus on these individuals due to the scarcity of research on their experiences and the relevance of their perspectives to engineering education.[29-31] Implications of this work will focus on recommendations for educational research and practice.

Framework and Literature

The overall EPS project is broadly situated in social cognitive career theory (SCCT) which posits that a variety of factors influence career choice including self-efficacy beliefs, outcome expectations, and learning experiences.[32] SCCT has been used extensively in the study of engineering students' career choices.[33-37] A main goal of our study has been to identify the school and workplace factors related to the career choices made by engineering graduates. Of particular interest is how they choose to pursue engineering or non-engineering work.

However, before we could begin to understand this choice, we had to operationalize what "pursuing engineering" actually means. Previously discussed criteria have included whether an individual self-identifies as an engineer, has an engineering job title, or earned their last degree in engineering.[11,16] Other researchers have asked if respondents are working in an engineering field,[2,5] if they consider themselves to be an engineer,[7,38], or if their work is related to their engineering degree.[12-13] Still others have focused on the proportions of graduates who plan to pursue engineering at some point in their careers, irrespective of what they are doing now.[6,8-9] There are thus many ways that pursuing engineering work might be defined, each with its own purposes and advantages.

In the current work, we cross-tabulate one definition of pursuing engineering work, i.e., employment in an engineering occupation, with six additional measures in order to develop a more nuanced understanding of persistence in the field. Such an understanding not only sets the stage to explore career choices in future research, but can help improve the career preparation and counseling that engineering students receive both during and beyond their undergraduate education. We chose occupation as our primary definition for two reasons: (1) it is one of the most common ways used to define retention, and (2) as a categorical outcome, it offers more clarity in meaning, and more variability in response, than other, binary (e.g., engineering vs. non-engineering) measures. The six additional measures examined from our survey include (a) one's own description of his or her position as engineering or non-engineering, (b) self-identification as an engineer (irrespective of current position), (c) engineering degree-job relatedness, (d) importance ratings of engineering competencies to their current work, (e) engineering degree attainment, and (f) future plans to pursue engineering work. We examine identity and the importance that graduates assigned to engineering competencies based on findings showing that nearly three in four engineering graduates not working in an engineering field still identify themselves as engineers because they use problem solving and other technical skills in their daily work.[2] We also looked at future plans since nearly 80 percent of engineering juniors and seniors plan for an engineering career, even if not immediately after graduation, which suggests long-term commitment to being an engineer.[9]

Methods

The overall EPS project uses an exploratory sequential mixed-methods approach[39] to examine transitions from being an engineering undergraduate to being an early career professional. Findings from in-depth interviews with 36 early career engineering graduates were used to inform the PEARS instrument for broader sampling. This paper is based on data from the PEARS survey. We compare a standard definition of pursuing engineering work, current occupation, with other definitions for an exploratory, mostly descriptive analysis of engineering graduates' early career choices.

Data source

The PEARS instrument was designed with two goals: to explore the early career work experiences and perspectives of engineering graduates, and to identify the educational and workplace factors related to their initial career choices. PEARS was framed in SCCT [32] and influenced by pilot interviews with early career engineering graduates,[40-42] findings from our prior research on undergraduates,[9,43-44] and other career research.[45-46] The final version of the instrument featured 45 questions covering five domains: degrees and employment; pre- and post-graduation learning experiences; self-efficacy, outcome expectations, and interests; career satisfaction and plans; and background characteristics. Several rounds of pilot testing and review were conducted with engineering graduates, faculty members, and administrators prior to survey administration.

Participants

PEARS was administered online in fall 2011 to engineering graduates who earned their engineering bachelor's degree from four institutions in 2007. The four institutions were all U.S.-based research universities that participated in our prior research on undergraduates (references blinded). They included a medium-sized, private liberal-arts university, a small, private technical institution, and two large, public comprehensive universities.

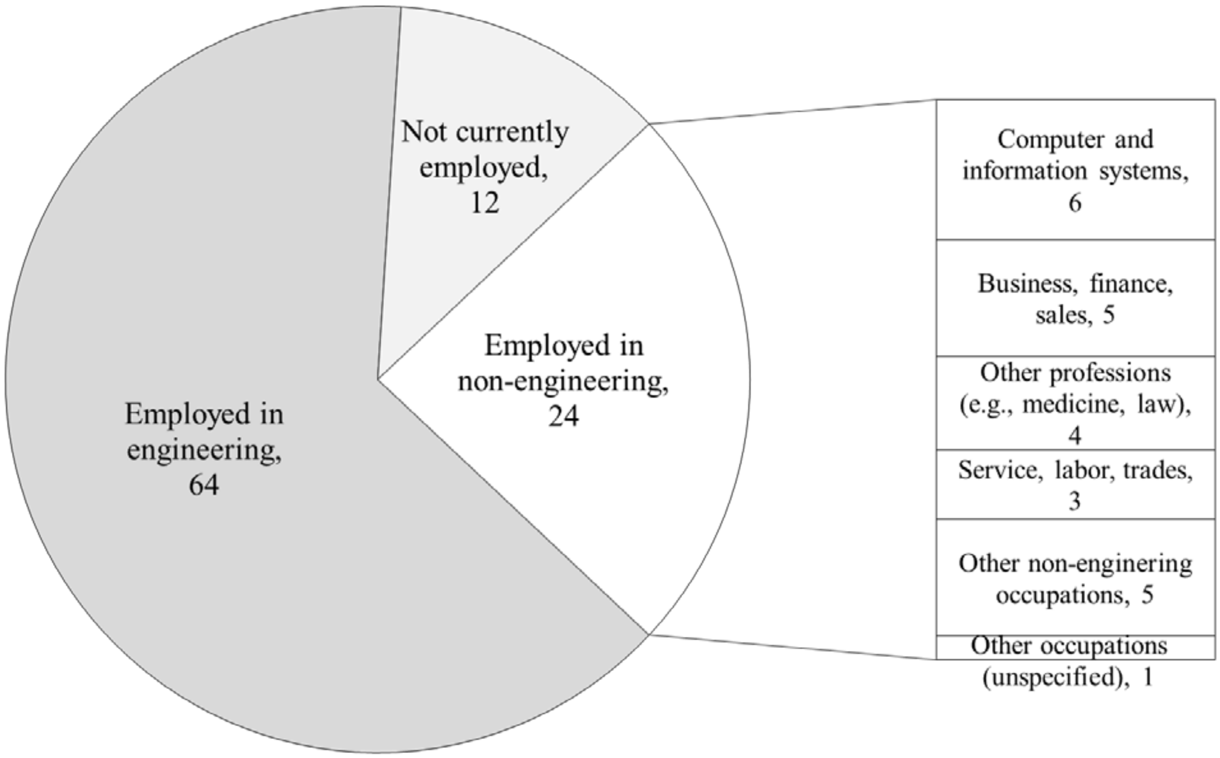
In 2007, the four institutions graduated a total of 2,520 engineering students, and in fall 2011, we had working e-mail addresses (provided to us by the four schools' engineering alumni associations) for 1,801 of them. Of these 1,801 graduates, a total of 543 responded to our survey. These data were weighted first for differential response rates by gender and major at each institution, and second for differential sampling rates, ranging from 53% to 91%, across institutions. Applying these two weights, multiplied together, allowed us to better approximate aggregate responses as if all 2,520 graduates had responded. However, because only 484 respondents actually finished the survey (i.e., they reached the last survey question, whether they completed the survey fully or partially), the total weighted n for our final sample was 2,249.

Sample for this study

In this study, we primarily classified respondents in terms of their current occupation. Occupational lists on the survey were constructed based on job codes in the NSF Science and Engineering Statistical Data System[22] which itself is adapted from the U.S. Bureau of Labor Statistics (BLS) 2000 Standard Occupational Classification.[45] Respondents were classified as employed if they indicated their current position as full-time or part-time, non-graduate school-related employment. They were further classified into one of seven occupational subcategories based on their current field and sub-field, as illustrated in the appendix. (Note: The grouping of fields and sub-fields into occupational categories was of our own design, based on patterns in the data, and not based on groupings by the NSF or BLS.) These subcategories were engineering; computer and information systems; business, finance, or sales; other professions such as medicine or law; service, labor, or trades; other non-engineering occupations (comprised mostly of "other mid-level managers"); and "other" occupations (unspecified). For some analyses, respondents in the non-engineering categories were combined into one, for comparison against respondents in the engineering category. Respondents not currently employed were omitted from all but our initial analyses due to their generally small numbers and heterogeneous composition (i.e., respondents who were full-time students, respondents who were neither employed nor enrolled, etc.).

Figure 1 shows the resulting distribution of all graduates in the PEARS sample based on their current occupation at the time of the survey. Four years after graduation, 64 percent of graduates were employed in engineering occupation, 24 percent were employed in non-engineering occupations, and the balance was not employed. Those working outside of engineering were most often employed in computer and information systems occupations, followed by business, finance, or sales occupations and "other non-engineering" occupations.

Figure 1. Percentage distribution of respondents by occupation (wt n=2,249)



The PEARS instrument also asked respondents for several demographic measures, including gender (female/male), race/ethnicity, and engineering undergraduate major. For race/ethnicity, 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". Graduates marking more than one option or "other" were combined into a single category. For undergraduate engineering major, respondents could choose from 24 engineering disciplines from a dropdown menu. These disciplines correspond to those used in degree lists for the NSF SESTAT surveys,[22] as well as majors unique to our partner institutions. For reporting, we show the seven most populous majors, each of which comprised more than five percent of the sample, plus "all other majors".

As shown in Table 1, there were several statistically significant differences between graduates employed in engineering occupations and graduates employed in non-engineering occupations. Graduates employed in engineering occupations were significantly more likely to come from mechanical (22% versus 8%) or chemical (14% versus 3%) engineering majors and significantly less likely to come from industrial engineering (4% versus 19%) majors than graduates employed in non-engineering occupations were. Graduates employed in engineering occupations were also significantly less likely that graduates employed in non-engineering occupations to be Black/African American (4% versus 1%). No other demographic differences between graduates employed in engineering and non-engineering occupations were statistically significant.

Table 1. Demographic measures, by occupational category (wt n=1,983)

Variable	All employed (100.0)	Employed in engineering (72.0)	Employed in non-engineering (28.0)	
	Percentage who are:			
Gender				
Female	22.9	21.3	27.1	
Male	77.1	78.7	72.9	
Race/ethnicity				
White	72.0	73.6	67.9	
Asian/Asian American	18.0	16.5	21.8	
Hispanic/Latino(a)	3.4	3.6	2.9	
Black/African American	2.0	1.1	4.4	*
Native Hawaiian/Pacific Islander	0.1	0.1	0.0	
Multiple races or “Other”	4.5	5.1	4.5	
Undergraduate engineering major				
Mechanical engineering	18.3	22.2	8.1	**
Electrical and related engineering	14.9	16.3	11.0	
Civil engineering	10.9	13.9	2.9	***
Chemical engineering	9.6	9.8	8.8	
Computer and systems engineering	7.8	6.8	10.6	
Industrial and manufacturing engineering	7.8	3.6	19.1	**
Aerospace and related engineering	6.3	7.5	3.1	
All other majors	24.5	19.9	36.3	

Used Fisher’s exact tests for employed in engineering vs. employed in non-engineering groups.
*** $p<0.001$, ** $p<0.01$, * $p<0.05$.

Our sample is comparable to the national population of engineering graduates who earned their degrees at or around the same time. Data from the NSF 2008 National Survey of Recent College Graduates show that 62 percent of the national population were employed in engineering occupations, 29 percent were employed in non-engineering occupations, and nine percent were not employed.[22] Additionally, the NSRCG sample and our sample show similar demographic patterns, with the exception that in our sample, non-white groups tend to be underrepresented, while women and “all other majors” tend to be overrepresented, among both engineering and non-engineering groups. These discrepancies may be explained in part by the differences between the NSRCG study and our study. We surveyed respondents at four institutions, while the NSRCG surveyed respondents across a national sample of institutions. It is possible that surveying engineering graduates from a wider range of institutions would result in demographic proportions more similar to those seen nationally.

Data analysis

This paper compares one definition of engineering, graduates’ current occupation, with six other measures: the description of one’s position as an engineering position, self-identification as an engineer, degree-job relatedness, importance ratings of technical competencies to their current work, engineering degree attainment, and future plans to pursue engineering work. Each alternate measure was selected from the PEARS instrument based on its potential to contribute new information about how engineering graduates conceptualize their current and future work as pursuing or not pursuing engineering.

Analyses for this paper followed a two-step process. First, we cross-tabulated the six alternate measures with our two overall occupational categories, employed in engineering occupations and employed in non-engineering occupations. Fisher's exact (2x2) tests and Mann-Whitney U tests were performed to evaluate between-group differences, and a p-value of $p<0.05$ was considered to be statistically significant. All tests were run using adjusted sample weights to minimize the possibility of artificially inflated effect sizes.

In the second step, we cross-tabulated the six alternate measures with all seven of our occupational subcategories. We strongly underscore that, although quantitative survey data are used, these analyses were descriptive and did not employ statistical testing due to small cell sizes. However, by focusing on differences in the six alternate measures by occupational subcategory, we were able to identify differences among graduates who pursue different occupations, and especially different non-engineering occupations, e.g., graduates employed in computer and information systems, in business, finance, and sales, etc. From these differences, we infer trends which we propose as the basis for further investigation.

Measures of pursuing engineering

Our first alternate measure of pursuing engineering work, *description of position as an engineering position*, asked respondents, "Would you describe your current and primary employed position (or most recent position if not currently employed) as: ... ?", with options, "an engineering position" or "a non-engineering position". The second measure, *self-identification as an engineer*, asked respondents, "Do you currently identify yourself as an engineer?". Respondents could answer "yes", "no", or "not sure".

The third measure, *degree-job relatedness*, was asked as, "How do you see your current employed position (or most recent position if not currently employed) as relating to your undergraduate engineering education?", and measured on a five-point response scale, from 0="not related" to 4="extremely related".

The fourth measure, *use of engineering competencies*, was actually a set of measures based on respondents' importance ratings of various competencies in their current work. Respondents were asked to rate the importance of twenty competencies on a five-point scale, from 0="not important" to 4="extremely important". These competencies derived from the ABET 2011-2012 Criterion a-k student outcomes[46] and the key attributes listed in the National Academy of Engineering (NAE) *Engineer of 2020* report.[47] In this paper, we focus only on the ABET outcomes, which were listed on the survey as shown in Table 2.

Table 2. ABET Criterion a-k outcomes

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

Note: Some outcomes were separated into multiple stems to capture individual competencies. Refer to the table footnotes below for the original wording.

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".

The fifth measure considers whether the *last degree* that respondents pursued or were currently pursuing was an engineering degree. This measure was created based on respondents' answers to which (if any) graduate or professional degrees they had earned, and which (if any) degrees they were currently pursuing.

The sixth measure, *future plans to pursue engineering work*, was based on the question, "Looking ahead, do you see your current future career path as: ...". Respondents had as options, "primarily pursuing engineering work", "primarily pursuing non-engineering work", "pursuing both engineering and non-engineering work", and "I do not know". For this paper, we combined the first and third options to create a measure related to whether graduates planned to pursue at least some engineering work in the future.

Results

Comparison by overall occupational category

Table 3 presents PEARS responses to the six alternate measures of pursuing engineering, by overall occupational category (employed in engineering occupations or non-engineering occupations). The results show that, four years after earning their engineering bachelor's degrees, the two groups significantly differ on more than just occupational designation.

Table 3. Measures of pursuing engineering, by overall occupational category (wt n=1,983).

Variable	All employed (100.0)	Employed in engineering (72.2)	Employed in non-engineering (27.8)	
	Percentage who marked:			
Describes position as engineering [a]	77.5	93.6	35.4	***
Current position "very" to "extremely" related to undergraduate engineering education [b]	44.8	53.1	23.5	***
Identifies self as an engineer [a]	79.8	93.8	43.6	***
Skills "very" to "extremely" important to current position [b]				
Communication	90.6	92.0	86.9	
Problem solving	89.2	92.0	81.9	**
Analytical skills	86.2	88.6	80.0	
Teamwork	84.8	86.5	80.4	
Professionalism	79.1	78.6	80.2	
Ethics	67.1	68.7	63.0	
Engineering techniques/tools	57.1	70.4	22.5	***
Lifelong learning	55.3	56.8	51.5	
Design	42.9	51.3	21.3	***
Math	38.0	41.3	29.6	***
Planning/conducting experiments	34.4	39.9	20.5	***
Science	33.0	38.5	18.7	***
Economic issues	25.9	25.2	27.6	
Global/societal context	24.7	21.8	32.3	
Environmental context	20.1	24.1	9.6	***
Last degree earned or current degree pursuing was an engineering degree [a]	85.0	91.4	68.2	***
Plans to pursue at least some engineering work in the future [a]	80.6	88.0	61.3	***

a. Used Fisher's exact tests for employed in engineering vs. employed in non-engineering groups. *** $p<0.001$, ** $p<0.01$, * $p<0.05$.
b. Used Mann-Whitney U tests for employed in engineering vs. employed in non-engineering groups. *** $p<0.001$, ** $p<0.01$, * $p<0.05$.

Compared with their counterparts in engineering occupations, graduates employed in non-engineering occupations were significantly less likely to describe their position as an engineering position (94% versus 35%), and to see their current position as "very" or "extremely" related to their undergraduate engineering education (53% versus 24%). In addition, they ascribed significantly less importance to most of the technical ABET outcomes[46] (e.g., engineering techniques/tools, design) in their work, while ascribing similar importance to all but one professional outcome,[46] environmental context. Lastly, graduates employed in non-engineering occupations were significantly less likely to self-identify as an engineer (94% versus 44%), to have an engineering degree as the last degree they earned or were pursuing (91% versus 68%), and to have plans to pursue at least some engineering work in the future (88% versus 61%). Thus, it would appear that graduates employed in non-engineering occupations see themselves, on every one of these measures, differently than do those employed in engineering occupations.

Comparison by occupational subcategory

When looking at these same measures by occupational subcategory, we identify more nuanced differences in the ways that engineering graduates may or may not be doing, participating, or contributing to engineering work. These differences suggest that some graduates employed in non-engineering occupations are farther removed from graduates employed in engineering occupations than are others.

For instance, of the graduates employed in non-engineering occupations, those employed in computer and information systems were the most likely to consider themselves as having an engineering position (50%, compared to 35% or less for all other groups; Table 4, top row). It is therefore somewhat surprising that these same individuals are among the least likely to see their current position as "very" to "extremely" related to their undergraduate engineering education (14%; Table 4, second row). Also with respect to degree-job relatedness, graduates employed in the service, labor, and trade occupations were unsurprisingly the least likely to see their current position as related to their education (0%), while graduates employed in business, finance, and sales were the most likely to (57%).

In addition, between 40 and 50 percent of graduates in every non-engineering subcategory except for "other" (unspecified) self-identified as an engineer (Table 4, row 3). For graduates employed in computer and information systems and in services, labor, or trade occupations, this percentage trended closer to 50 percent. By comparison, just 40 percent of graduates employed in both the professions and other non-engineering occupations self-identified as an engineer.

Table 4. Measures of pursuing engineering, by occupational subcategory (wt n=1,983.

Variable	Engineering occupations (72.2)	Computer/ Information Systems (7.0)	Business, finance, sales (5.4)	Other professions (e.g., health and law) (5.0)	Service, labor, trades (3.2)	Other non-engineering Occupations (5.4)	Other occupations (unspecified) (1.7)
	Percentage who marked employed in:						
		Non-engineering occupations					
Describes position as engineering	93.6	50.4	33.0	31.0	28.6	35.2	5.9
Current position "very" to "extremely" related to undergraduate engineering education	53.1	13.7	23.6	56.6	0.0	20.4	20.0
Identifies self as engineer	93.8	48.6	44.3	41.4	50.8	42.1	20.0
Skills "very" to "extremely" important to current position							
Problem solving	92.0	90.6	70.8	82.8	73.0	80.4	100.0
Engineering techniques/tools	70.4	30.0	6.6	20.2	28.6	27.1	20.0
Design	51.3	40.3	9.4	30.3	7.9	12.1	5.9
Math	41.3	25.2	42.1	26.3	34.4	24.3	25.7
Planning/conducting experiments	39.9	14.3	21.7	22.0	19.0	33.6	0.0
Science	38.5	5.8	0.0	43.4	14.6	29.9	14.3
Last degree earned or current degree pursuing was an engineering degree	91.4	73.6	82.1	42.4	73.4	66.4	74.3
Plans to pursue at least some engineering work in the future	88.0	76.4	66.3	41.4	77.8	58.9	22.9

We also examined the technical ABET outcomes on which graduates employed in engineering and non-engineering occupations significantly differed (Table 4, rows 4-9). To the extent that engineering fundamentally involves technical problem solving, graduates employed in computer and information systems most resembled those graduates employed in engineering, followed by graduates employed in the professions and in other non-engineering occupations. (Note: The graduates employed in "other" occupations (unspecified) also rated problem solving as very important; however, due to lack of further insight into this group, we report their data but we exclude them from our discussion.) Graduates in these occupational groups also assigned high ratings to other technical competencies, such as design (likely software and hardware design) among graduates employed in computer and information systems, and science and planning/conducting experiments among graduates in the professions and other non-engineering occupations. Graduates employed in business, finance, and sales, as well as in service, labor, and the trades, assigned high importance ratings to math, but low ratings to all other competencies. Finally, none of the graduates employed in any of the non-engineering occupations found engineering techniques/tools important to the degree that graduates employed in engineering did.

After engineering, the business, finance, and sales group had the second-highest proportion of graduates who last earned, or were currently pursuing, an engineering degree (82%; Table 4, row 10), while graduates employed in the professions (including health and law) and in other non-engineering occupations had the lowest (42% and 66%, respectively). This trend corresponds to graduates' degree attainment patterns in general, since graduates in business, finance, and sales were least likely to have pursued additional degrees (35%) while graduates in the professions and in other non-engineering occupations were the most likely (64% and 44%, respectively).

Future plans to pursue at least some engineering work followed the same trend as self-identification as an engineer (Table 4, row 11). More than three-quarters of the graduates employed in engineering, in service, labor, and trade occupations, and in computer and information systems planned to pursue at least some work in engineering in the future, while 41 and 59 percent of graduates employed in the professions and other non-engineering occupations, respectively, had this goal.

Trends across occupational subcategories

In terms of our six alternate measures of pursuing engineering, graduates employed in computer and information systems appear to be more similar to graduates employed in engineering than are respondents in every other sub-occupational group. Nearly equal proportions of graduates employed in engineering and in computer/information systems rated problem solving – arguably the most important skill in engineering work[2,38,49-50] – as "very" to "extremely" important, while this skill was rated lower among the other groups. Furthermore, graduates employed in computer and information systems were among the most likely to describe their current position as an engineering position (50%) and to self-identify as an engineer (49%), noting that these proportions were still much lower than those found among graduates employed in engineering (94% for both).

For further insight into graduates employed in computer and information systems, we divided them into two groups: (1) those employed in computer-related occupations (63%), including computer programming, software development, and computer-related management and consulting, and (2) those employed in information technology (IT) related occupations (37%), including computer support, computer system analysis, and network system administration. The two groups differed only slightly in their importance ratings of the technical ABET outcomes to their work. However, compared to graduates employed in IT-related occupations, graduates employed in every computer-related occupation were more likely to see their current position as an engineering position (70% versus 17%) and to self-identify as an engineer (63% versus 25%), even though 42 percent had earned or were pursuing their latest degree outside of engineering, typically in computer and information science. (Graduates employed in IT-related occupations, on the other hand, had not earned, nor were they pursuing, any kind of advanced degree.) In addition, nearly 40 percent of graduates employed in computer-related occupations had majored as undergraduates in computer or systems engineering, compared to just 20 percent of graduates employed in the IT-related occupations. These results suggest that graduates employed in computer-related occupations might be more aptly considered as working in occupations strongly affiliated with engineering, despite ongoing debates of whether software engineering should be considered as such,[51-52] while graduates employed in IT-related occupations might be considered as working in occupations less closely affiliated with engineering. Nevertheless, despite differences in the ways they viewed their current positions and identities, roughly three quarters of both groups reported plans to pursue engineering work in the future.

Unlike graduates employed in computer and information systems, graduates within each of the other non-engineering subcategories did not divide cleanly into more than one group. (For example, no major differences were found between graduates employed in business or finance and graduates employed in sales.) Two clusters of occupations were identified *across* the four subcategories, however.

The first cluster was comprised of business, finance, and sales, and services, labor, and trades. The graduates in these occupations tended not to see their current position as an engineering position, or to rate many of the technical competencies as "very" to "extremely" important except math. However, of all graduates employed in non-engineering occupations, they were among the most likely to self-identify as an engineer, to have an engineering degree as their last degree earned or pursuing, and to have plans to pursue engineering work in the future. Therefore, groups may be classified as not currently working in engineering but with plans to return in the future.

The second cluster was comprised of the professions (e.g., health, law) and other non-engineering occupations. Graduates in these occupations also tended not to see their current position as an engineering position, although they did rely substantially on problem solving and other technical competencies, especially science and the ability to plan and conduct experiments. They were the least likely to self-identify as an engineer, to have an engineering degree as their last degree earned or pursuing, and to have plans to pursue engineering work in the future. (Common last degrees for this group included biological or physical science, health, law, and business.) On the whole, then, this group appears to currently be working outside of engineering with no plans to return to engineering in the future.

Thus, to summarize, four types of graduates appear to emerge from the data: (1) those who see their current position and identity as engineering-related and who plan to continue in engineering work going forward (i.e., graduates employed in engineering and computer-related occupations), (2) those who do not view their current position and identity as engineering-related and who do not plan to pursue engineering work later (graduates employed in the professions and other non-engineering occupations), (3) those who view their identity, but not their current position, as engineering-related and who plan to pursue engineering work later (graduates in the business and service related occupations), and (4) those who do not view their position or identity as engineering-related but who do plan to pursue engineering work later (graduates in IT occupations).

The existence of the second type, graduates who do not view themselves or their jobs as engineering and who do not have engineering plans, appear to support the notion that some engineering students never intend to pursue an engineering career but instead see their undergraduate degree as a stepping stone to other opportunities.[31,44]

The third type, on the other hand, calls attention to two sub-types of graduates. Graduates of the first sub-type are not working in engineering, but they still identify as engineers and plan to return to engineering at some point, i.e., whom Margolis and Kotys-Schwartz call "returners".[6] Graduates of the second sub-type identify as engineers and want an engineering career but, for some reason, might not have been able to work in an engineering job at the moment. The data suggest that graduates employed in the services, labor, and trades may be of the second sub-type since they include those currently enlisted in the armed services, those employed in the food services while they pursue advanced engineering degrees, and those graduates employed in administrative or trade occupations due partly (based on their responses to an open-ended question at the end of the survey) to the economic downturn or to issues surrounding visa status. Less clear from these data is why early career engineering graduates defer engineering positions for business, finance, and sales occupations; further work is needed to understand these reasons.

Graduates in the fourth type, i.e., those who do not identify at all with engineering but who have engineering plans, pose an interesting conundrum. While our previous examples posit a link between engineering self-identification and future engineering employment, this example does not. Understanding the true causal nature of the relationship between these measures thus represents another area for further research.

Insights into engineering measures

Besides providing a framework by which to classify graduates, our results reveal important additional information about the various (mostly self-report or self-defined) measures used in this study. First, graduates' descriptions of their position as an engineering position apparently rely more on just their occupational title or even the extent to which they use problem solving and other technical competencies in their work. More research is needed to explore the types of career activities in which graduates are engaged and why they do or do not consider these activities to be engineering work. Previous findings suggest that whether graduates are involved in the making of an actual, tangible product and how their colleagues perceive their work might be factors,[36,49] and that other graduates might draw still different boundaries.

Through our cross-tabulations, we can also begin to infer new reasons for the generally poor fit between degree-job relatedness and occupational title.[15] In short, it is possible that different groups of engineering graduates interpret this measure differently. Graduates in the services, labor, and trades may not rate their job as "very" or "extremely" related to their undergraduate engineering education because they are not using the technical aspects of their degree (e.g., engineering problem solving). Graduates employed in the computer-based occupations, on the other hand, have been shown to use the technical aspects of their degree; however, this particular group of graduates may not perceive their job as related if, for example, they learn one programming language or set of software algorithms as undergraduates, only to have to learn completely different ones on the job. We note that graduates employed in the professions were the most likely to consider their current position and their engineering degree as related. It is possible that these graduates are finding jobs that allow them to creatively apply their education to other fields (Margolis and Kotys-Schwartz refer to this situation as non-problematic attrition[6]). Equally possible is that they simply interpret relatedness more broadly than do other graduates. Our results therefore suggest that respondents could be interpreting degree-job relatedness in terms of the skills they use, the tools they interact with, and the extent to which they have been able to achieve their career goals, among other ways. Future work can expand on these findings by probing how engineering graduates interpret degree-job relatedness more directly.

Conclusions and Recommendations

In this study, we used several measures to determine how early career engineering graduates conceptualize themselves as doing (or not doing) engineering work. By this method, and despite the reliance on small cell sizes, we gained new understanding about which occupations outside of the traditional engineering workforce might still be considered as engineering related. For example, our findings suggest that graduates employed in computer-related occupations, while not technically engineers based on categories in the NSF SESTAT surveys,[22] might still be classified as working in engineering. We also confirmed plans among several non-engineering groups to return to engineering work after some time.[23,53]

Recalling that a central focus of this work was to support SCCT as a framework for understanding post-graduation retention, a measure of doing engineering work based on graduates' occupation and perceptions of current position has been chosen and serves as the basis for this forthcoming work. In terms of additional research, our findings foremost encourage further study into the meanings of certain self-defined engineering measures. In particular, more work is needed to understand how graduates conceptualize their current position, their extent of degree-job relatedness, and their self-identification as an engineer. A follow-up, mixed-methods study is recommended for this task, featuring interviews and surveys with engineering graduates from a more diverse sampling of institutions and graduation years, as well as the targeted recruitment of those employed in non-engineering occupations. We also recommend exploring relationships with other measures such as undergraduate major and occupational sector. Finally, the results of this paper point to a need for longitudinal work, to better understand how engineering graduates' occupations and perceptions of doing engineering work change and inform each other over time.

In terms of recommendations, we encourage engineering programs to routinely gather information from their graduates, including not just their current occupations, but whether they identify as engineers and what skills and knowledge they use in their daily work. Data from engineering graduates can help to decide which career paths to emphasize in engineering courses, internships, and research experiences, as well as which recruitment and retention initiatives to implement. We urge engineering programs to prepare students for a broad range of career pathways, including non-engineering occupations in which engineering graduates nonetheless use their degrees (e.g., computer professions). Educators can additionally emphasize interdisciplinary career options, to potentially attract graduates wanting to enter another profession after graduation. Finally, it is recommended that engineering programs provide students with firsthand exposure to professional engineering workplaces, so that they may begin drawing connections between engineering education and real-life engineering practice. This understanding can potentially increase students' perceived degree-job fit (i.e., the perception that they are using their engineering degree regardless of their job title), which may in turn positively impact their overall career satisfaction.[54-55]

Based on our findings, we also suggest improved career counseling and advising, particularly for engineering students planning to return to engineering after an extended period away. Students' reasons for not pursuing an engineering career immediately after graduation vary, from wanting to pursue both engineering and non-engineering options,[6,9,44] to needing to postpone their plans due to a poor economic climate.[56] No matter the reason, once in a non-engineering job, graduates have fewer opportunities to update their engineering skills and consequently may find it increasingly difficult to return to engineering.[13,29,57] It is therefore crucial that engineering programs help students hone their engineering skills and explore different engineering career options while still in school. Preparing students to return to engineering may also increase the diversity of the field, especially if underrepresented groups (for instance, parents[58]) are more likely to take "gap" time. Educators should also promote lifelong learning and continuing education at the graduate and certificate levels. With respect to finding work, campus career development centers can help students and graduates by circulating job postings, hosting career fairs, and holding on-site interviews. Finally, in preparation for the unexpected, such as during an economic downturn or under geographical constraints, faculty and advisors can also coach students and alumni to think broadly and entrepreneurially about their employment options.

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Appendix. PEARS occupations by occupational subcategory

Employed in engineering
Engineers or engineering-related technologists
Consultants – Engineering
Managers and supervisors, first-line – Engineering
Managers and supervisors, mid-level – Engineering
Research associates/assistants – Engineering
Teachers and professors, post-secondary – Engineering

Employed in computer/information systems
Computer-related occupations
Consultants – Computer/information systems (CIS)
Managers and supervisors, first-line – CIS
Managers and supervisors, mid-level – CIS
Research associates/assistants – CIS
Teachers and professors, postsecondary – Computer Science

Employed in business, finance, or sales
Business and financial operations specialists
Sales occupations, including securities and commodities
Teachers and professors, postsecondary – Business, Commerce and Marketing

Employed in other professions (e.g., medicine, law)
Architects
Artists, entertainers, athletes, and media workers
Clergy and other religious workers
Counselors
Health workers
Legal workers
Consultants – Education
Consultants – Management
Consultants – Medical/health services
Library workers
Managers, first-line – Education
Managers, first-line – Medical/health services
Managers, mid-level – Education
Managers, mid-level – Medical /health services
Managers, top-level (e.g., CEO, COO)
Research associates/assistants – Education
Research associates/assistants – Medical/health services
Social workers
Teachers, precollege
Teachers and professors, postsecondary
- Art, Drama, and Music
- Education
- Health and Related Sciences

Teachers, other

Employed in service, labor, or trades
Clerical or administrative workers
Farmers, foresters, and fishermen
Military personnel
Service workers, except health
Grounds cleaning and maintenance workers, etc.

Employed in other non-engineering occupations
Biological and life scientists
Consultants – Natural sciences
Consultants – Other
Counselors
Managers, first-line – Natural sciences
Managers, first-line – Other
Mathematical scientists
Physical scientists
Research associates/assistants – Natural sciences
Research associates/assistants – Other
Social scientists
Teachers and professors, postsecondary
- Agriculture
- Biological Sciences
- Chemistry
- Earth, Environmental, Marine science
- Economics
- English
- Foreign Language
- History
- Mathematics and Statistics
- Physical Education
- Physics
- Political Science
- Psychology
- Sociology
- Other Natural Sciences
- Other Social Sciences
- Other Postsecondary Fields

Employed in other occupations (unspecified)
“Other” occupations