UNDERSTANDING THE PROFESSIONAL, NON-ACADEMIC EXPERIENCE OF ENGINEERING FACULTY

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Abstract
The literature in both Engineering Management (EM) and the nascent field of Engineering Leadership (EL) periodically discusses the relative importance of industry experience for faculty engaged in these areas. Recent work in both fields found that EM / EL faculty appear to have considerable industry experience. However, this finding runs counter to the commonly accepted knowledge summarized by former leaders of the National Academy of Engineering Wulf and Fischer as "Present engineering faculty tend to be very capable researchers, but too many are unfamiliar with the worldly issues of 'design under constraint' simply because they've never actually practiced engineering." While this knowledge is commonly accepted, prior reviews of the literature were unable to identify any studies that quantified this lack of practice experience among engineering faculty. A finding further supported by discussions with engineering education programs officers at the NAE.

This work seeks to close that gap through examination of the backgrounds of a representative national sample of engineering faculty. The collection looked at faculty from fifteen different universities representing each of the three Carnegie research classifications. For each university, faculty backgrounds from three different programs were collected and examined using faculty's publicly available curriculum vita and professional social media identity (i.e. LinkedIn). Through this analysis a composite profile is created that shows the differences in practice backgrounds of faculty, considering type of appointment (level, tenurable vs. non-tenurable) and engineering field. Significant differences are found in many categories, supporting some aspects of the commonly held beliefs.

Keywords
engineering faculty, professional skills, engineering education

Introduction and Motivation
The purpose of this study is to better understand the level of non-academic professional and leadership that engineering faculty possess. The motivation to understand these backgrounds is two pronged. First, as pressures increase on academia to produce graduates who are ready for the workforce (Inglis, 2016; Selingo, 2015), some are revisiting the call started by Boyer (1990) nearly 30 years ago regarding how scholarship is practiced at universities. If both the role of the university and the types of scholarship considered worthy within higher education are changing, the preparation of faculty may also need to change. Second, there is growing recognition of the need for engineers with well-developed professional skills (ABET, 2012; National Research Council, 2004; Passow, 2012). If faculty are to support the development of these professional skills, perhaps they need to have experienced them in a professional setting.

The development of this study grew from prior work to understand the professional and academic background of engineering faculty engaged in the field of engineering leadership and how the broader engineering faculty view leadership and define leadership in an engineering context (Schell & Kauffmann, 2016). That work found that faculty who are engaged in engineering leadership research have an unusually high level of non-academic professional experience when compared with what is understood to be the typical engineering faculty member, with 98% of study respondents holding professional experience outside academia. This conflicts with the commonly held notion that the average engineering faculty holds little experience actually doing engineering, a point made by no lower authority than William Wulf, former president of the National Academy of Engineering (NAE), and George Fischer, former chair of the NAE council when they stated, "Present engineering faculty tend to be very capable researchers, but too many are unfamiliar with the worldly issues of 'design under constraint' simply because they've never actually practiced engineering" (Wulf & Fisher, 2002). Surprisingly, this commonly held and accepted notion has little empirical support. Existing studies of engineering faculty profiles generally examine education, academic experience, and demographic information, not non-academic experience (National Science Foundation Division of Human Resourses Statistics, 2015). This study seeks to close that gap by developing a national sample of engineering faculty intended to represent the breadth of engineering schools within major engineering disciplines. The backgrounds of faculty selected will be examined through their published curriculum vita.

Research Methods

In order to develop this national sample of engineering faculty backgrounds, a stratified sampling approach was employed (Brewerton & Millward, 2011). The strata selected included the type of school where the engineering faculty are currently employed, as defined by Carnegie research classifications (Indiana University Center for Postsecondary Research, 2015) and the discipline of the faculty member. Complete details regarding the methods utilized are detailed in the following sections.

School Selection

Selection began by identifying universities or colleges from which to sample engineering faculty. Using the stratification defined previously, a total of 15 schools were selected (fourteen randomly plus the authors' school, Montana State University), five from each of Carnegie research classifications. The R1 Schools were selected from ASEE's top 50 engineering schools ranking by graduate count (Yoder, 2015) to reduce the number of additional drawings required, while the R2 and R3 were selected from the published listings of all schools of these classifications. With the exception of Montana State University, all selections were based on selecting a school based on the output of a random number generated with a range of values to match the list length. When a school was selected that did not have an engineering program, it was dismissed and the random number generator was employed again to select a new school. Exhibit 1 shows which schools were selected in each of the three categories.

Exhibit 1. Schools Selected for Data Collection

R1 Universities
Georgia Institute of Technology
Stony Brook University
Texas A&M
University of Iowa
University of Wisconsin-Madison

R2 Universities
Baylor University
Lehigh University
Montana State University
University of Maryland-Baltimore County
University of Texas at El Paso

R3 Universities
Boise State University
California State University-Fullerton
East Tennessee State University
Kennesaw State University
Texas A&M University-Kingsville

Faculty Selection

Once universities were selected, faculty needed to be selected and their experience evaluated. For each school selected, faculty from a total of three difference departments (or programs for some schools) were randomly sampled. In order to maintain consistency with the types of faculty evaluated, departments or programs were selected using the following priority list:

1. Mechanical – accounting for nearly 25% of Bachelor's degrees awarded and more than twice as many as the next highest program (Yoder, 2015), ME was a clear first choice.
2. Civil – CE was selected as the next highest enrollment program nationally.
3. Industrial (and similar, including Industrial and Systems and Engineering Management) – IE is the primary interest area of the research team and most attendees at the ASEM International Annual Conference.

If one of these departments or programs was not present, replacements of Electrical Engineering or Chemical Engineering were selected (the third and fourth highest U.S. enrollments, respectively). For smaller schools with limited engineering programs, when a total of three programs was not available from these five, their next largest department or program, based on enrollments, was utilized.

From each department or program, 10 tenurable faculty were randomly selected for evaluation. In departments with less than 10 tenurable faculty, a census of the tenurable faculty was performed and non-tenurable faculty members were then randomly selected to make up the difference. In any departments or programs with less than 10 total faculty, a complete census was performed. In combined departments such as Mechanical and Industrial Engineering, faculty were randomly selected from the combined department and captured by discipline rather than department. Selected faculty were then evaluated to determine the presence of a publicly available curriculum vitae (cv), generally on their faculty web page or available through a web search of the faculty member's name. When no cv was available, key information on their university webpage and professional profile on LinkedIn were used to collect information. Faculty with no public cv or LinkedIn profile were not recorded and another faculty member from that department or program was randomly selected in their place. This process resulted in an overall sample of 408 faculty. Of these, 396 either were tenured or held tenurable positions at their institution. Since over 97% of the sample drawn were tenurable faculty and there are known differences between the profiles of tenurable and non-tenurable faculty (Schuster & Finkelstein, 2007), all data analysis discussed in this paper is restricted to the 396 tenured or tenurable faculty.

Faculty Experience Evaluation

Faculty's curriculum vitae and LinkedIn profiles were examined using a standardized rubric and standard process. The review process included review of the cv beginning with the faculty member's education to determine the year that professional or academic experience might begin (based on the year of earning the first degree). From there all listed positions were reviewed to determine type (academic, industry / professional, military) and level (leadership / administrative or other) and the years of experience of each type and level. Faculty were assigned to a discipline based on their department affiliation. When departments represented multiple disciplines, the faculty member was assigned based on the area of focus of their terminal degree, in cases where the terminal degree did not match the faculty's department, the discipline was assigned based on their research areas and the alignment of those areas with the disciplines in the department. The key variables collected through this process were:

- Faculty institution type and discipline
- Years of academic experience
- Years of full time industry / professional experience – excluding internships or consulting work by faculty
- Years of military experience
- Presence of academic administrative positions (e.g. dean, chair, etc.)
- Presence of industry leadership positions (e.g. manager, team-leader, president, etc.)
- Presence of military leadership positions (e.g. captain, officer, etc.)

When present in the curriculum vitae, number of peer reviewed publications and latest publication date were recorded. No data on peer reviewed publications was recorded from LinkedIn profiles. The scoring rubric was reviewed and finalized by the research team prior to utilization and then piloted using faculty from Montana State University. Once these pilot faculty were scored, the scoring was reviewed either with the faculty member being scored or a colleague closely familiar with the prior work history of the subject. Any discrepancies noted were utilized to revise the scoring rules prior to proceeding to score faculty from the other 14 schools.

Analysis and Interpretation

Since the purpose of this study is the development of a profile of the non-academic and leadership experience of engineering faculty, the data analysis presented here focuses on the demographics of the reviewed faculty. Additional analysis is presented to compare certain cohorts, but is secondary to the primary thrust.

Overview of the Engineering Faculty Sample

Exhibit 2 presents an overview by school type and discipline of the 396 tenurable faculty. A few anomalies in the data deserve explanation. First, there are not 150 faculty featured in any slice of the data. This is due to the removal of non-tenurable faculty. Second, the exhibit shows fewer faculty in both R2 and R3 schools than in R1 schools. This is because some of these schools had fewer than 10 faculty in their sampled departments or programs. Finally, there are more than 50 ME faculty in the R2 schools. This occurred because one of the sampled schools had both an ME department where 10 faculty were included in the sample and a General Engineering department where nine of the faculty were from the ME discipline.

Exhibit 2. Breakdown of Faculty Sample by School and Discipline

	Discipline					
Classification	**CE**	**ChemE**	**EE**	**IE**	**ME**	**Average**
R1	48		4	39	50	141
R2	30	10	19	21	58	138
R3	38		30	11	38	117
Average	116	10	53	71	146	396

Exhibit 3 presents the next overview of the data, examining the total years experience (academic + industry + military) of faculty, again by school type and disciple. In this view, one sees that the average years of experience moves little with a change in disciple and appears to be higher for R2 schools than the others. Statistical analysis using one-way ANOVA in Minitab 17 (Minitab, 2018) confirms this appearance finding no difference by discipline ($p = 0.997$) and a significant difference by school type ($p < 0.001$). These findings may simply indicate that the average tenurable faculty at R2 schools are later in their career than their peers at other institutions.

Exhibit 3. Total Years of Faculty Experience by School and Discipline

	Discipline					
Classification	**CE**	**ChemE**	**EE**	**IE**	**ME**	**Average**
R1	15.95		6.38	16.64	16.05	15.90
R2	24.13	17.80	21.05	18.49	18.45	20.00
R3	12.29		16.12	12.59	14.42	13.99
Average	16.87	17.80	17.15	16.56	16.58	16.77

Understanding the Experience Types of Engineering Faculty

The next level of analysis investigated the industry / professional experience of engineering faculty, for this analysis military experience was not included as only seven faculty members in the sample possessed this experience (< 2%). Exhibit 4 shows the average years of industry / professional experience by school type and discipline. As may be easily seen, there is little difference between the groups in terms of experience levels. ANOVA analysis using Minitab 17 confirms that there are no significant differences present ($\alpha = 0.10$). Perhaps most concerning from these numbers, with a global average of only 1.73 years of industry / professional experience, this area of experience accounts for less than 10% of the total experience of the sample. Said another way, over 90% of engineering faculty members' total experience is in academia, providing empirical support to the commonly held beliefs discussed in the introduction.

Exhibit 4. Years of Professional / Industry Experience by Faculty Type

	Discipline					
Classification	**CE**	**ChemE**	**EE**	**IE**	**ME**	**Average**
R1	0.81		0.00	1.38	1.38	1.15
R2	1.60	0.70	0.95	3.73	1.89	1.89
R3	2.78		1.35	3.18	2.09	2.23
Average	1.66	0.70	1.10	2.36	1.77	1.73

While the averages provide initial confirmation of the lack of industry / professional experience within engineering faculties, they mask some potentially important information – specifically what proportion of engineering faculty possess non-academic engineering experience that could be considered meaningful. For this work, the threshold for meaningful experience was drawn at 5 years. This threshold was determined based on discussions within the research team, with members of the college's advisory board, and a number of other engineering managers in the authors' professional network. Examining the number of engineering faculty with this experience level, the proportions displayed in Exhibit 5 were developed.

Exhibit 5. Proportion of Faculty with 5 or More Years Professional / Industry Experience

Classification	Discipline CE	ChemE	EE	IE	ME	Average
R1	4.2%		0.0%	10.3%	10.0%	7.8%
R2	16.7%	10.0%	10.5%	19.0%	13.8%	14.5%
R3	15.8%		10.0%	18.2%	15.8%	14.5%
Average	11.2%	10.0%	9.4%	14.1%	13.0%	12.1%

The table illustrates minor differences in the proportion of faculty holding meaningful professional experience both by school type and discipline. Of these differences, the only ones that hold any level of statistical significance ($\alpha \leq 0.1$) were that a lower proportion of faculty at R1 schools held substantial professional experience vs. their peers at R2 ($p = 0.075$) and R3 ($p = 0.090$) schools. This finding is intuitive given the level of emphasis placed on research activity at R1 schools vs. others. At an aggregate level, there were no differences in this measure between the disciplines.

Limitations

While efforts were made to draw a representative sample of engineering faculty and the overall sample size is reasonably large, this study intentionally drew samples from specific disciplines and makes no claim that it is representative of all engineering faculty in the United States. For example, it would be unreasonable to draw conclusions from this sample about Chemical Engineering faculty, as only 10 are included. In addition, while a robust process and rubric were developed for analyzing faculty curriculum vita, the wide variety of what faculty include in their vita and how often they update it makes it likely that the underlying data contains inconsistencies and inaccuracies. While the research team has no reason to believe that these issues contain a specific pattern of biases (e.g. generally understating the years of experience or eliminating non-academic related experience), readers are cautioned that these patterns might exist. Finally, there is a risk of sampling bias in these results. As discussed in the methods, if a faculty member did not have either an online cv or professional social media identity, they were skipped and replaced with another. It is possible that there is a hidden pattern of bias in the presence or absence of these items, which would lead to a bias in this data.

Conclusions and Future Work

This study provides the first known broad sample of the professional, non-academic experience of engineering faculty in the U.S. and as such begins to empirically support, and in some cases refute, the generally accepted knowledge about the actual engineering experience of engineering faculty. More importantly for the team's future work, this study provides a comparator data set to understand the differences between general engineering faculty and those engaged in the scholarship of engineering education to improve the leadership and other professional skills of engineering students. This new data set shows clear differences from the findings of earlier work regarding the professional backgrounds of those engaged in engineering leadership development (Schell & Kauffmann, 2016). In addition, this work has examined only a portion of the data collected, for example this paper does not discuss the differences in leadership positions held by faculty members, as this additional data is analyzed, it may provide further insights about faculty preparation.

The evidence continues to indicate that the engineering professorate is not doing enough to change the way engineers are educated and adequately respond to societal needs that engineers are prepared to lead diverse, interdisciplinary teams (National Research Council, 2005; National Science Board, 2007). In fact, one of the leaders of the engineering education movement has noted that "what academic discipline other than engineering has faculty members who have never done something in their lives (design, for example) teaching students to do it professionally" (Felder, 2013). These statements explicitly point to a lack of professional experience in engineering faculty beyond academia and that this experience gap presents a potential barrier to developing the kinds of professional skills that society needs from its engineers. Perhaps one reason that faculty engaged in areas such as engineering management and engineering leadership have higher levels of actual engineering experience is that they have closed their own "knowing / doing gap" that exists between empirical research of what works in the engineering classroom and actual practice. If this is the case, it has meaningful implications for what changes are needed in the engineering professorate to truly be able to not only educate the engineer of 2020, but those who will be practicing in 2050.

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