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Engineering Leadership: Faculty Perceptions and Profiles

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Engineering Leadership: Faculty Perceptions and Profiles

Abstract
This work augments our understanding of faculty perceptions of engineering leadership and its place in engineering curricula. As evident by the scholarly activity, development of a new division within ASEE, and attendance at the sessions for that division, engineering leadership is an area of increasing interest among the engineering education community. However, discussions at a 2015 conference panel appeared to show that this interest is not uniform across all members of the professorate. Based on observations in this session and others, there appears to be a relationship between the faculty member's level of professional experience from outside the academy and his or her degree of commitment to the importance of including engineering leadership in the curriculum. Whether this experience was in a military or industrial setting, it appears to heighten the perceived need for engineering educators to provide methods to develop engineering leadership skills within their undergraduate students.

This study investigates this apparent split using two sources of information: the background of authors publishing in recent engineering leadership literature and a national survey of engineering educators. The first source involves analysis of information on authors actively publishing in engineering leadership. Using this information, the paper identifies biographical information common to those who appear to be most engaged in the topic and compares it to existing national faculty profiles. These findings are augmented through national survey of engineering faculty. The survey investigated faculty perceptions on the importance of engineering leadership development and the manner faculty think these materials should be incorporated in engineering curricula. These perceptions are investigated with respect to participant's backgrounds and experiences outside the academy. This work will be of interest to both faculty building commitment for and materials supporting integration of engineering leadership in the curriculum and the engineering leadership profession.

Introduction
Many of the greatest challenges facing society today require technical solutions that can only be created through collaboration within interdisciplinary teams.[1] For these collaborations to effectively harness the capabilities of groups that may not normally work together, effective technical leadership must be deployed. Thus, the need for engineering leadership (EL).

As evident by the development and growth of the Engineering Leadership Development Division (LEAD) within the American Society of Engineering Education (ASEE), recognition of the need to develop engineers with greater leadership skills is gaining momentum. However, observations during LEAD's sessions at ASEE's 2015 Annual Conference & Exposition seemed to indicate that faculty engaged in LEAD activities did not share the same background as the typical engineering educator. Specifically, participants appeared to have a far greater level of non-academic experience than most engineering faculty. This appears to indicate the curricular and research activities related to engineering leadership are being led by nontraditional background academics. If true, this observation would run counter to the commonly held notion that too few engineering faculty have the needed professional experience to effectively train the skills needed by the engineers of the future. Or more bluntly, as noted by William Wulf, former president of the National Academy of Engineering (NAE), and George Fischer, former chair of the NAE council, “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.”[2] This study investigated both the accuracy of this observation and the perceptions of EL held by a sample of engineering faculty through a national survey.

Findings from the Literature

The concept of engineering leadership is a relatively new one in engineering education, with most publications on the topic and formal programs to develop it appearing in the last ten years.[3] In fact, a 2009 formal review of engineering leadership programs found only eight worthy of consideration for best practices.[4] While in 2007 a seminal text on improving engineering education addressed leadership development needs, but did not find them important enough to include in the index.[5] During the past five years, this state of affairs has changed dramatically with over a dozen programs participating in the inaugural COMPLETE Leadership Conference,[6] the development of several named EL centers through the support of generous endowments,[7, 8] a new division of ASEE focused on engineering leadership,[9] and dozens of papers investigating engineering leadership skills at the annual ASEE conference.[10]

Recognition of the importance of EL is part of an increasing movement toward incorporation of curricular materials that promote developing engineers who meet the broad needs of today’s industry. This direction is driven by a number of pressures, including changes in engineering accreditation criteria,[11] calls from seminal reports such as the *Engineer of 2020,*[12] and evidence from engineering graduates that indicate professional-skills are often what engineers find most important in the workplace.[13] Unfortunately, the evidence continues to indicate that the engineering professorate is not doing enough to change the way engineers are educated and adequately respond to these changing societal needs.[14-16] As noted by participants at a 2013 National Academy of Engineering Forum, “If curricula was redesigned around the needs of the students, rather than the needs of faculty members, they would look quite different.”[17] Given these broader perceptions of the limited importance faculty place on professional skills, the second aspect of this study was to examine the importance that faculty place on EL and what EL should include if incorporated into already full engineering curricula.

Study Methods and Approach

This study sought to test the hypothesis that the faculty engaged in EL development come from a different background than those of the larger engineering faculty. The specific research questions addressed were:

1. What is the career profile of EL engaged faculty?
2. Does this profile appear to differ from that of the general engineering faculty?
3. Are EL engaged faculty more likely to hold non-tenurable appointments than traditional engineering education active faculty?
4. How do faculty demographics differ between those who believe EL is an important aspect of engineering education and those who do not?
5. Is there a consensus on what EL content should be and how it is delivered?

To examine these research questions, two sources of information were developed and analyzed. The first source involved analysis of biographical information of authors actively publishing in the LEAD division of ASEE. Using this information, the study identified biographical information common to those who appear to be most engaged in the topic and compared it to existing national faculty profiles. These findings are augmented through the results of the study's national survey of engineering faculty. This survey investigated faculty perceptions on the importance of engineering leadership development and the manner faculty think these materials should be incorporated in engineering curricula. These perceptions were then investigated with respect to participant's backgrounds and experiences outside the academy. The following sections discuss these sources in more detail.

Faculty Profile Information

EL engaged faculty were defined as those who had published an ASEE LEAD conference paper from the 2013-2015 conferences. These papers were downloaded and author background was categorized using both the ASEE biographical summary and information on the authors obtained from web searches. The following biographical data was documented:

- Did the author have industry experience? If so, what was the duration?
- Was the industry experience primarily technical or did it include industry leadership?
- Did the author have military experience and did that include service as an officer?
- If the author is currently in an academic position, is the position a traditional tenured or tenure track appointment or is it a "professor of practice" or similar non-tenurable appointment?

Faculty Perceptions of Engineering Leadership

To augment these findings, a survey was developed and deployed to examine faculty perceptions about the role engineering education should play in the development of engineering leadership skills in undergraduate students. The survey was distributed to ASEE members through electronic means using Program Chair emails. The survey gained the greatest level of participation from members of the Civil, Engineering Management, Engineering Technology, and Industrial Engineering groups. The survey questions explored faculty perceptions of engineering leadership and their perceived role of engineering leadership content in engineering and engineering technology programs. The broader goal of this survey was to understand what engineering educators identify as important topics in the concept of Engineering Leadership and their overall impression of the importance of Engineering Leadership in undergraduate curricula.

Data and Findings

Both data collection methods collected demographic information from over 100 participants. To provide insight into the backgrounds and characteristics of authors actively publishing in engineering leadership over the last several years, the study examined the authors of 46 ASEE LEAD publications. This group consisted of 114 different individuals and the study found information from public sources on current and past career experiences for 108 of these authors. The national survey of faculty obtained 154 participants who began the survey instrument. Of these, 123 completed the full questionnaire (80%). Participants represented a wide range of engineering disciplines and familiarity with Engineering Leadership programs.

Data Demographics – LEAD Authors

The background of the authors and their biographical characteristics are summarized below. Since detailed biographical information was not found for all authors, a number of these factors reflect a minimum or "at least" value:

- Of the 108 authors, 14 were graduate students in various disciplines ranging from engineering education to construction management. 11 were undergraduates. Together, students represented 23% of the total number of authors
- Of the remaining 83 authors who were not students, 40 (48%) had industrial experience. These authors averaged 12.8 years experience and 16 (40%) of those with industry experience had management experience while in industry.
- Six of the 83 (7%) had military experience and all of these served as officers.
- 15 of 83 (18%) had academic leadership experience as a department chair, associate dean or similar positions.

From a current career perspective, the 83 non student authors could be grouped into a number of categories:

- 15 of the 83 (18%) were involved in a leadership institute at their university in a nontraditional academic role such as professor of practice. An additional 4 authors (5%) were also involved in engineering leadership institutes but were in traditional academic positions. Overall, 23% of authors represented university leadership institutes.
- 52 of 83 (62%) currently fill traditional academic appointments, not affiliated with an engineering leadership program. This includes many disciplines other than engineering.
- 10 of 83 (12%) are in academic positions other than faculty. This includes positions such as program recruiter and director of first year programs.
- Only two authors were not in academic positions.

To explore the background of the perceived leaders in the engineering leadership literature, an additional analysis of only the first authors was completed:

- Although 23% of the total non-student authors were involved in academic leadership institutes, only 13% of the lead authors were from this group.
- 41% of the lead authors held traditional academic appointments vs 48% of the total authors.
- Students represented 23% of the total authors but 32% of the first authors. Graduate students being 24% and undergraduates 8%.
- Authors in academic positions other than faculty represented 12% of the total authors and 14% of the lead authors.
- Neither of the two non-academic authors were lead authors.

Several themes are evident in the background of the LEAD authors.

- 23% of the authors are students with approximately 10% undergraduates. Leadership study is clearly an area of interest for students.
- Students represented nearly one third of the lead authors with graduate students alone being about one fourth. This is a positive indicator that a number of graduate programs are supporting engineering leadership research.

- 55% of the authors have work experience outside of academia and 65% possess work experience in a leadership position. This is much higher than expected. Although data on the industry experience of engineering professors was not specifically identified, typical estimates are reflected by a recent publication by the National Society of Professional Engineers which stated that … "few engineering faculty today have practical experience in design, analysis, review, or management of engineering projects."[18]
- 22% of authors represent university leadership institutes, indicating these organizations are playing a significant role in contributing to the scholarship in this field.
- Contributions from authors in nontraditional and nonacademic positions are also substantial with 38% of authors currently working in these areas. Again, this proportion is much higher than anticipated considering a recent study by the AAUP which found approximately 20% of university faculty were in nontraditional positions.[19]

Data Demographics – National Survey Participants

Participants in the national survey represented a wide range of engineering disciplines and differing levels of familiarity with Engineering Leadership programs. Only 28% of respondents came from universities with a formal, defined leadership program for engineering students while only 6% of respondents from schools without such a program knew of plans to start one. Respondents represented more than 13 different engineering disciplines with the heaviest representation coming from Civil (38%) and Engineering Technology (17%). These percentages differed significantly[i] from the general engineering educator population where Civil and related disciplines represent 13% of tenured or tenurable faculty.[20]

Faculty experience and position were also varied. The sample generally included faculty with a substantial experience level in the faculty role with 70% having 10 or more years while only 14% had between two and five years of experience, 3% less than five years and 3% never having held a faculty role. The sample included 61% tenured faculty, 17% tenure track and 22% non-tenurable with over 75% having held an academic role other than their current position. This included 59% administrative roles and 20% of tenured or tenurable respondents having previously held non-tenurable roles. A full 98% of respondents possessed professional experience outside of the academy. This included 38% with ten or more years of industry or military experience.

Ethnicity responses included 82% Caucasian participants, 8% Asian, 6% none selected, 2% Hispanic, 1% African American and 3% other. Survey respondents were 76% male, 18% female with 6% preferring not to answer. The African American, Hispanic, and gender numbers are in line with those of national surveys, while the percentage of Caucasian respondents is significantly higher and Asian respondents is significantly lower.[21]

Faculty Perceptions on the Importance of Engineering Leadership

In general, survey respondents were strongly supportive of EL as a discipline for undergraduate engineers with 60% of participants noting it is a very or extremely important (hereafter "high importance") component of undergraduate engineering education while only 11% found it slightly important, of low importance or not important at all (hereafter "little importance"). A substantial number (26%) of respondents selected the middle response of "moderate"

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[i] - Significance indicated at an α value of 0.1 throughout this work.[18]

importance, these respondents were not included in the following analysis. Investigating differences in faculty profile information for the high importance vs. little importance groups found the following:

- The proportion of non-tenurable faculty indicating EL is of high importance was significantly higher than tenured / tenurable faculty (two proportions test, p = 0.051).
- The data was unable to provide any insight into the difference non-academic professional experience plays in the belief in the importance of EL, as 98% of respondents had at least some experience and over 70% had more than five years experience. However, this overwhelmingly high level of experience, when compared with the sample obtained from LEAD authors or general profiles of engineering facutly,[2, 23, 24] provides some indication of a relationship between industry experience and an interest in EL.
- Of those who felt engineering education's role was of high importance, nearly 75% agreed that engineering educators were in an influential position to help undergraduates understand the importance of leadership to their careers and that it was important for these students to see leadership in an engineering context. It is a point of concern that only 18% felt engineering educators were well qualified to teach leadership to their students.
- 58% of the high importance group thought that at least half of their peers would agree that EL is of high importance. By comparison the group that thought EL was of little importance felt significantly less confident that their opinion was in the social norm, with only 15% thinking that at least half their peers would agree with their position (Fisher's exact test, p = 0.006).
- Respondents supported a variety of reasons that EL is a high importance component of undergraduate education, including: improving student's career success (72%), the need for effective communication (78%), and the role of leadership in influencing the organization (81%). The strongest reason for this support was based on the professional obligation of engineers, where 85% of respondents agreed that without strong EL, the role engineers hold with respect to solving society's greatest challenges will be diminished. One respondent took this further, stating "We have a moral and ethical responsibility to create the very best leaders....that is our very mission as post-secondary educators."

Armed with this understanding of why educators felt that EL is an important component of undergraduate education, the study used the survey data to explore how these educators defined EL. This investigation included understanding what topics are considered part of EL and the role of undergraduate education to prepare students in these areas.

Faculty Perceptions on the Content of Engineering Leadership and How to Develop It

As discussed in the methods section, the survey also asked a series of questions designed to elicit an understanding of what engineering faculty think are the most important components of EL. For this analysis, respondents were broken into the high importance and low importance groups defined earlier. Then, for each skill, the number of respondents who viewed that skill as very or extremely important were investigated. As summarized in Table 1, there are significant differences in how respondents define the components of EL and the role they believe undergraduate education plays in developing these components between those who view EL as very important and those who do not. For example, while both groups agree that education

Definition of EL - Very or Extremely Important Abilities for New Graduate Engineers

	Develop Feasible Solutions to Technical Problems	Write Effective Memos and Technical Reports	Deliver Effective Presentations	Work in Teams as a Team Leader	Work in Teams as a Team Member	Utilize Project Management Tools	Understand the System or Organization Wide Impact of Solutions	Analyze the Strategic Implications & Business Case of Solutions	Understand and Harness Employee Motivation	Understand the Financial Implications of Engineering Decisions	Take Responsibility to Serve the Profession and Community
High EL Importance Group (n = 78)	59 (76%)	67 (86%)	69 (89%)	73 (94%)	70 (90%)	49 (63%)	70 (90%)	56 (72%)	54 (69%)	56 (72%)	61 (78%)
Little EL Importance Group (n = 13)	7 (54%)	5 (39%)	5 (38%)	8 (62%)	9 (69%)	1 (8%)	5 (38%)	8 (62%)	4 (31%)	11 (84%)	8 (62%)

Importance to Develop Through Undergraduate Education - Very or Extremely Important Components

	Develop Feasible Solutions to Technical Problems	Write Effective Memos and Technical Reports	Deliver Effective Presentations	Work in Teams as a Team Leader	Work in Teams as a Team Member	Utilize Project Management Tools	Understand the System or Organization Wide Impact of Solutions	Analyze the Strategic Implications & Business Case of Solutions	Understand and Harness Employee Motivation	Understand the Financial Implications of Engineering Decisions	Take Responsibility to Serve the Profession and Community
High EL Importance Group (n = 78)	72 (92%)	71 (91%)	72 (92%)	67 (86%)	72 (92%)	50 (64%)	55 (71%)	49 (63%)	43 (55%)	53 (68%)	64 (82%)
Little EL Importance Group (n = 13)	11 (83%)	11 (85%)	10 (77%)	5 (38%)	8 (62%)	1 (8%)	1 (8%)	4 (31%)	1 (8%)	6 (46%)	4 (31%)

[shaded] Indicates a significant difference between high and little importance groups (Fisher's exact test, $p < 0.05$)

Table 1 – Summary of Faculty Perceptions on the Content of Engineering Leadership and How to Develop It

should develop student's technical writing skills (91% and 85% respectively), of those who view EL as high importance 86% view writing as part of EL, while only 39% of the low importance group view it in the same manner. The views of an engineer's skill at leading project teams and performing project management are even more polarized. 94% of respondents who view EL as high importance include team leadership as part of their highly important skills and 86% view it as highly important that this skill be developed in undergraduate engineers. For project management skills these numbers are 63% and 64% respectively. Investigating these same categories for respondents who view EL with low importance, the numbers significantly lower: team leadership at 61% and 38% and 8% for respective dimensions of project management.

Similar to the analysis of the importance of EL, respondents who believe that EL is of high importance are generally more confident that their view of the definition of EL is in line with a majority of their peers than are those who place a low importance on EL. When asked what percentage of their peers would generally agree with the choices and ratings related to defining the abilities important to EL, 59% felt that over half their peers would be in agreement, while only 23% of the little importance group felt this way, a significant difference (Fisher's exact test, $p = 0.032$).

Conclusions and Implications

The investigation of the backgrounds of educators engaged in EL research or who view EL as an important component of undergraduate education has added to our understanding of how educators come to be involved in this field. First, curricular and publication innovation in engineering leadership appears to be originating from individuals with specific industry, military and leadership experience. The representation of individuals with this type of background in the ASEE LEAD authors and in the survey is substantially higher than would typically be expected, especially when engineering education luminaries like Richard Felder are noting 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."[24] Second, respondents to the survey further reinforced this unusually high level of non-academic professional experience with 98% of respondents having some experience of this type and over one third having a decade or more.

This is consistent with the authors' previous study which examined the transition from industry into academia.[25] In general, despite the fact that industry experience might not be widely valued in the academic job search process, it is important to recognize that it will be valuable in teaching and is generally highly valued by students.[23, 26] Students are more engaged when they can see how the abstract material they are learning can be applied in their careers. When instructors can draw from a deep set of experiences to show applications, they are better able to paint the picture that connects these dots. This appears to also be the case in engineering leadership.

The study also reinforced the relationship between the so called ABET professional skills and those of Engineering Leadership. The topics which received consensus (defined as 75% of respondents or higher) both as being very or extremely important abilities for new graduates and important topics to include in undergraduate engineering education included:

- Develop feasible solutions to technical problems
- Write effective memos and technical reportsDeliver effective presentations

- Work in teams as a team leader
- Work in teams as a team member
- Take responsibility to serve the profession and community

EL focused educators are encouraged to leverage this alignment with both existing and proposed ABET criteria in order to gain further momentum for EL and assist their peers with more traditional academic backgrounds recognize the importance of this emerging area of engineering education. These educators are encouraged to seek places in the curriculum where EL topics can be integrated into existing curriculum in a logical, if not seamless manner. This includes capstone courses, engineering ethics courses or modules, and project management courses.

If as we surmise, the EL curricular developments and research are being led by faculty with nontraditional academic positions and with industrial / leadership experience, an area of possible concern involves the long term limitation to EL work presented by this profile. Since faculty with these characteristics are limited in number in many institutions this may prevent EL from gaining widespread acceptance. In other words, while this demographic represents a very high proportion of both the active author and survey respondents, it is much less clear that they represent a meaningful percentage of the overall engineering faculty, or if the group is large enough to overcome areas of academic inertia to create this change.

Finally, this study highlights the fact that it is critical to more fully study and define a potential engineering leadership body of knowledge. This point is illustrated by the disparity in views of the importance of writing skills and project management skills. It will be critical for future development and expansion of leadership development that engineering program faculty can develop a shared vision of what engineering leadership means before seeking consensus on how to develop these skills in students.

Study Limitations

This survey of engineering educators is an exploratory study to begin to understand faculty opinions on the concept of engineering leadership. While the participation in the survey was over 100 participants and the demographics of those participants matched the demographics of the larger engineering faculty in many ways, the sample collected does have limitations. First, the sample was one of convenience using listservs and faculty professional groups readily available to the research team and is not necessarily a representative group of faculty. Second, since the survey was voluntary and made no use of incentives, it is reasonable that those who opted in are more likely than others to have a deep interest in EL. While this bias is acceptable considering that the survey data was utilized to build a profile of the perceptions and profiles of faculty interested in EL, it limits the ability to utilize this data for more wide reaching conclusions about the growth and future of EL as a unique sub-discipline.

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