
AC 2012-4490: RECOMMENDATIONS FOR PROMOTING DESIRABLE CHARACTERISTICS IN ENGINEERING PH.D.S: PERSPECTIVES FROM INDUSTRY AND ACADEMIA

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Recommendations for Promoting Desirable Characteristics in Engineering Ph.D.s: Perspectives from Industry and Academia

Engineering doctoral graduates often are criticized for being narrowly trained in their disciplines, for being ill-prepared for the professional workplace, for lacking leadership abilities, and for not being flexible in a changing global environment. Considering the challenges facing engineering Ph.D.s, it is necessary to recommend ways for engineering doctoral students to “hit the ground running” in their academic or industrial positions. This research presents information about the potential measures that can be undertaken in graduate education to facilitate the academic preparation of current engineering doctoral students. One-on-one semi-structured interviews were conducted with forty engineering professionals from academic and industrial sectors. The primary research question within this paper asks, “What can be done at the graduate level to ensure that engineering Ph.D. students are acquiring the desired characteristics to be successful in academic and industrial careers?” Our findings suggest that engineering Ph.D.s working in a variety of sectors identify different skills that students can acquire during their graduate school experiences. Both industry and academic professionals confirm a need for more frequent interactions between industrial professionals and doctoral engineering students.

Introduction

Engineering doctoral graduates often are criticized for being narrowly trained in their disciplines, for being ill-prepared for the professional workplace,¹ and for not being flexible in a changing global environment.² Multiple initiatives within the U.S. propose to implement changes in engineering education beginning with the Accreditation Board of Engineering and Technology (ABET)’s *Engineering Criteria 2000* in 1999.³ This was followed by the National Academy of Engineering (NAE)’s *The Engineer of 2020* in 2004⁴ and the National Research Council (NRC)’s *Rising above the Gathering Storm* in 2006.⁵ All of these reports focused on reconsidering the way engineers are educated in America. Nguyen emphasized the differences between the perceptions of academics, industry personnel, and students concerning essential generic and specialist skills and attributes of a modern engineer.⁶ Such skills are needed since Ph.D.s are often perceived to be leaders in their respective fields and are often hired to translate their technical knowledge to a variety of people in their work environments. Considering the challenges facing engineering Ph.D.s, it is necessary to recommend ways for engineering doctoral students to “hit the ground running” in their academic or industrial positions.

Given the criticisms of professionals in industry and the expectations of new engineering faculty to be proficient teachers and researchers, the current paper draws upon responses from forty engineering Ph.D.s to identify what can be done at the graduate level to ensure that engineering Ph.D. students are acquiring the desired characteristics to be successful in academic and industrial careers and to solicit ways to improve current engineering graduate education via recommendations from these interviewees. These suggestions may be used to facilitate the training of current engineering doctoral students in their acquisition of knowledge, skills, or attributes that are essential to career success and may be used to identify educational models for engineers who would like to explore multiple post-graduate pathways during their graduate experiences.

Background

In 2008, more than 15% of doctorate degrees were awarded to graduates in engineering fields.⁷ Although traditionally viewed as a degree leading to an academic career, engineering Ph.D. recipients have started pursuing careers in other fields. The pursuit of an academic career is further hindered because of the lack of tenure-tracked positions in the current economic climate. Statistics show that only 30% of engineering Ph.D. recipients were employed in academic tracks, while the remaining accepted employment outside of academe.⁸

Although a large proportion of Ph.D. degree recipients work in industry, Akay points out that these Ph.D. students receive very little training for positions in industrial settings.⁹ The gap between the desirable characteristics of Ph.D. degree holders from both academia and industry and the current training and professional preparation received by the graduate students justifies the need for change in engineering doctoral education.

There have been multiple efforts to facilitate doctorate students in their transitions either to a faculty career or to a career in industry. Recent initiatives such as “Preparing Future Faculty” have been launched to promote smooth transition of graduate students into faculty positions.¹⁰ Courses and workshops have also been developed to facilitate the transitions of graduate students to professional roles in industry.¹¹ Frameworks such as Golde and Walker’s “stewardship” framework have also provided insight into ways to train the next generation of doctoral students.¹² This framework has aligned with the purpose and practices of doctoral education across six doctoral disciplines, and hence allows a new opportunity to operationalize stewardship within engineering. The goal of this framework, which is to examine and to improve doctoral programs across the U.S., aligns with the objectives of this study to explore the possible measures to ensure that Ph.D. degree holders embody desirable characteristics required to be successful in both academic and industrial settings.

Methods

Participants

The research team interviewed forty (40) individuals from industry and academia who obtained engineering Ph.D.s from U.S. institutions. Eleven of the interviewees were women. Figure 1 classifies interviewees as working in one of four areas- Academia only (AC), Industry only (IN), Academia then Industry (AC-IN), and Industry then Academia (IN-AC). Figure 2 classifies interviewees by the discipline in which they obtained their Ph.D.s. The team made deliberate efforts to interview participants who obtained Ph.D.s in the top disciplines in which the majority of engineering Ph.D.s graduate (i.e., chemical engineering, mechanical engineering, and electrical engineering). Disciplines identified within the “other” category include biomedical engineering, materials science and engineering, aerospace engineering, and industrial engineering.

Participants were identified via convenience and snowballing strategies. Faculty in the three departments of interest in a Midwestern university were sent recruitment e-mails asking them to identify potential research participants, and a recruitment e-mail were distributed to appropriate

disciplinary and diversity-related listservs within the American Society for Engineering Education (ASEE) to recruit potential interviewees representing diverse sectors and perspectives.

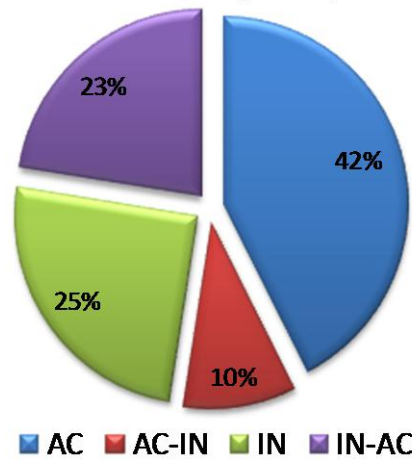


Figure 1- Breakdown of participants by Four Employment Sectors

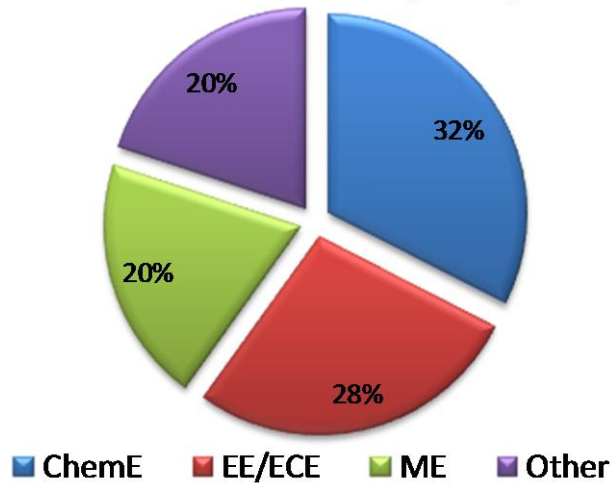


Figure 2- Breakdown of participants by Engineering Disciplines

Data Collection

The primary research question within this paper asks, “What can be done at the graduate level to ensure that engineering Ph.D. students are acquiring the desired characteristics to be successful in academic and industrial careers?” To understand different ways for current engineering doctoral education to help engineering Ph.D.s to acquire desirable skills, four researchers conducted semi-structured interviews with the forty industry and academic professionals. Each interview lasted approximately one hour with emphases on topics such as professionals’ motivations for obtaining a Ph.D. and characteristics and expectations of engineering Ph.D.s in industry and academia. Although fifteen questions were asked to participants, particular emphasis is placed upon the question that explores these professionals’ views of possible practices that can train graduate students to be successful after obtaining their engineering Ph.D.s.

Data Analysis

Results were analyzed from one protocol question-“What can be done at the graduate level to ensure doctoral students acquire the desirable characteristics (mentioned earlier by participants)?” The data analysis was conducted by four research team members. Each team member analyzed data from one or two sectors (e.g., Industry only or Academia only). Strategies on how to improve current engineering graduate education were coded. Transcripts from interviews were read and re-read to get a general sense of the data. The transcripts were then coded via open-coding. Open-coding was used to label a certain text segment and obtain the main idea of the text segment.¹³ After open-coding, the codes were compiled and grouped together. Similar codes were grouped into categories. The categories across the four different sectors were then compared with each other. After these coding efforts, one researcher compared the codes from all different sectors and summarized the major themes by comparing the codes across different sectors.

Results

An overview of our analysis highlights some overlaps in the recommendations that participants across the four groups proposed to improve current engineering graduate education. Still, distinctive points were identified, especially between the academia only group and industry only group in their emphases on the different aspects of engineering graduate education. Results for each sector are presented below.

Academia Only Responses

The participants from the academia only group emphasized the importance of bringing non-engineering stakeholders into engineering graduate education, students’ developing the skills to communicate technical issues in laypersons’ terms, and establishing a working relationship between advisors and graduate students by clearly stating expectations and allowing students to explore their own interests. They focused on students learning from each other and emphasized the necessity of being supportive yet critical to students’ ideas so that students can defend their research ideas effectively.

Academia-only respondents suggested recommendations for students and for institutions. *Students* should produce genuine and novel research ideas, do independent and grounded research and implement a research plan, be critical and rigorous in their research efforts, cultivate the skills of writing high quality journal publications, develop their teaching skills, build a teaching portfolio, and develop their ability to mentor others. *Institutions* should help students understand the mission of a university (e.g., teaching-focused versus research-focused); should expose them to the “bigger picture” (marketing, business, social, environmental issues), and should expose students to more breadth in the curriculum.

From the perspective of engineering programs or engineering faculty members, interviewees recommend that formal programs, workshops, seminars or courses be developed to help students understand the day-to-day life of a professor. In addition, considering the lack of real industrial experiences for some faculty members, more opportunities should be provided for engineering faculty members to obtain these industrial experiences. They also indicated that engineering programs should be more responsive to the needs and challenges of industrial settings.

Industry Only Responses

Similar to the academia only group, the participants from the industry only group also emphasize the importance of bringing different stakeholders into engineering graduate education. In particular, they stressed different ways to strengthen links between engineering graduate programs and industrial representatives and the potential for students to gain more industrial experiences. They stated the importance of students having hands-on experiences and developing practical skills such as project management or finance analysis skills. Similar to the academia-only group, the participants from the industry-only group also emphasized the importance of establishing working mentoring relationships between students and their advisors. Participants from industry highlight the importance of obtaining critical feedback from peers either on research ideas or presentation skills. They also stressed the importance of encouraging students to present regularly at different venues, to interact with people beyond their traditional research circles, and to attend professional conferences.

The key points in their recommendations to engineering graduate education relate to an introduction to skills that are *not* taught within a traditional engineering curriculum at the doctoral level. *Students* should gain hands-on experiences (e.g., interdisciplinary projects, lab work, and internships); should cultivate practical skill sets such as financial analysis and budgeting skills; should enroll in project management courses; and should increase their awareness of commercialization. *Institutions* should create workshops with industry professionals or bring in industrial representatives to interact with students; should emphasize rigor in students' communication skills; should help students to keep the end goal in mind; should assist students in the cultivation of a result-oriented mindset; should engage students in both research-based and industrial-based work; and should give students more responsibilities during their graduate experiences.

Academia-to-Industry Responses

Similar to the industrial-only group, participants in the academia-to-industry group stated the importance of students developing project management and business-type skills. Participants in this group also brought in expertise in bridging academia and industry expectations. They suggested the concept of academia-industry joint programs and suggested the following recommendations for *institutions*:

- Establish some academia-industry joint programs that introduce students to both environments
- Teach students how to delegate
- Teach students to critique their writing
- Allow students to present to funding agencies
- Promote interdisciplinary, collaborative work
- Align their programs to be more relevant to society

Industry-to-Academia Responses

Aligned with the key points presented in the above-mentioned three groups, the participants in this group also highlighted the importance of developing industrial experiences among students, students writing peer-reviewed high quality publications, the establishment of a working relationship between mentors and students, and encourage students to work with each other.

Besides these major points, the participants in this group also brought in additional insights from working in both industrial setting and academia settings. A recurring theme included participants wanting to see more rigor in academia to make sure that engineering graduate programs produce higher quality engineering Ph.D.s. What follows is a summary of their recommendations for *institutions*:

- Provide explicit ethics instruction
- Enforce high qualifying exam standards
- Develop a high quality graduate curriculum
- Emphasize rigor in both oral and written communication
- Avoid grade inflation at the undergraduate level
- Have students work on problems with breadth and depth
- Teach students to solve engineering problems

These respondents also recommended that the government provide more resources for graduate education.

Discussion

Many of the recommendations from the academia only group are heavily related to Ph.D. engineers whose possible future careers are in academia. Data show the importance of developing new research ideas, presenting high quality publications, and focusing on teaching and mentoring students. Similarly, industry only group recommendations focus mainly on the skills needed to be successful in industry. The need for hands-on experiences and industrial internships are mentioned. Unlike the emphasis on research skills mentioned from the academia only group, financial analysis skills, budgeting skills, and product commercialization are emphasized in industry only group.

Integration between higher education institutions and industry is recommended from the academia-to-industry Group. It is interesting to note that the two recommendations from this group that do not overlap with any other groups are presenting to funding agencies and promoting interdisciplinary collaborative work. It is possible to view these two recommendations as necessary skills to be successful in both academia and industry. Finally, the industry-to-academia group focuses on generating high quality engineering Ph.D.s through the development of a rigorous graduate curriculum.

Based on our preliminary findings from the four different groups of engineering professionals (academia only, industry only, academia-to-industry, industry-to-academia), several potential measures can be implemented within current engineering doctoral programs. First, bringing in non-engineering stakeholders into engineering graduate education can be useful for both engineering students and engineering faculty members. Strengthening the ties between academia and industry at the institutional level provides opportunities for students to develop both industrial and academia experiences. Meanwhile, it also provides venues for faculty members to build collaborations or gain more industrial experiences. Second, a curriculum with more breadth and depth needs to be implemented in engineering doctoral programs. A curriculum with more breadth and depth will allow students to situate engineering problems within a bigger picture while taking into consideration multiple perspectives such as marketing, business, and social and environmental issues. Third, it was suggested that engineering doctoral students should communicate clearly in both oral and written communication. On one hand, students need to

communicate within the professional community via publishing high quality, peer-reviewed publications and presenting at professional conferences and other venues. On the other hand, students should present regularly at multiple other occasions and should interact with more people to convey technical issues in layperson's terms.

Conclusions

Findings within this research note that engineering Ph.D.s who are working in academia and industry have numerous suggestions about ways that students can engage in activities to prepare them for diverse careers. Many of these suggestions do not relate to the traditional expectation of students to produce a dissertation and conduct quality research, however. With an emphasis on professional skill development and engagement in activities outside of a classroom environment, these suggestions can be a starting point for conversations at departmental levels about ways to engage industry professionals in current activities within doctoral departments and ways to expose students to activities that will prepare them to be leaders once they obtain their engineering doctoral degrees.

Acknowledgements

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