EEC Collaborative Research: Non-Academic Career Paths of Master's and PhD Engineers

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1 | Introduction

Despite trends in career trajectories of engineering graduates whereby the majority of Master's and PhD earners are interested in [1] and enter [2] jobs outside of academia, most of the existing graduate education research and resources focus on academic career paths [3], [4], [5], [6], [7], [8]. While ideally graduate students would receive equivalent support in pursuing either career path, the current culture privileges academic positions over non-academic career pathways [2], [9]. These current practices fall short of serving the majority of engineering graduates, who will end up in sectors such as private industry, government, or a non-profit organization. This completed project addresses this gap by qualitatively and quantitatively investigating (Table 1) the preparation of engineering graduate students for non-academic careers (i.e., government labs, industry, start-up, non-profit), and how graduate school experiences impacted those decisions, experiences, and outcomes. This poster presents the project's findings in aggregate. Three research questions guided this project:

- RQ1: What are the large-scale non-academic career trajectories of engineering doctoral students, and how do those trajectories vary across institutions and engineering disciplines?
- RQ2: How are graduates of engineering Master's and doctoral programs exposed to, preparing for, and making decisions about future careers in various non-academic sectors (government labs, industry, start-up, non-profit)?
- RQ3: How are engineering faculty/staff/administrators informing students about and helping students prepare for future careers in various non-academic sectors (government labs, industry, start-up, non-profit), and how does that vary across institutions and engineering disciplines?

Table 1. Data sources and applications to research questions

Data source	**RQ1**	**RQ2**	**RQ3**
Survey of Earned Doctorates [10]	x		
Interviews with structural engineering executives	x	x	
Survey of current engineering PhD students		x	
Interviews with current engineering PhD students and postdocs		x	
Interviews with recent graduates		x	
Interviews with engineering faculty, staff, and administrators		x	x

2 | Outcomes: Research

The findings from this project have been published in five journal articles [11], [12], [13], [14], [15], three conference papers [16], [17], [18], and one publicly available report [19].

RQ1: Large-scale non-academic career trajectories of engineering doctoral students

To answer RQ1, we presented percentages of engineering PhD earners who pursue non-academic careers immediately after graduation [13], [19]. Using data from the Survey of Earned Doctorates (SED) [10] for all engineering and computer science graduates from 2015-2019, 48% (n = 16,383) obtained careers in industry; 33% (n = 11,124) obtained positions in four-year institutions, medical schools, or university-affiliated research institutes; 8% (n = 2,846) obtained positions in government); 6% (n = 2,078) obtained positions outside of the United States; 3% (n = 987) obtained positions in the non-profit sector; and 1% (n = 483) obtained jobs in other sectors. As detailed in [13], [19], PhD earners from different demographics (e.g., gender, race/ethnicity, citizenship, marital status, having dependents) pursue job sectors at different rates. Computer engineering, electrical engineering, and computer science PhD earners predominantly pursued industry careers (65%, 62%, and 56%, respectively). Biological/biomedical engineering and environmental engineering were the only fields in which PhD earners did not predominantly enter industry; instead, these graduates favored careers at four-year institutions, medical schools, or university-affiliated research institutes. Another discipline-specific finding from the greater project is that within structural engineering, some companies prefer to hire master's students rather than PhDs, who they feel are overqualified, too expensive to hire, and have expertise that is too niche. When given the choice, a thesis-based master's is preferable compared to a coursework-only master's because writing a thesis allows students to develop their critical thinking and communication skills [16]. We hope that these findings–particularly, the prevalence of PhD earners pursuing industry careers–will motivate engineering educators and program leaders to provide more professional development opportunities focused on non-academic careers.

RQ2: How engineering Master's and PhD graduates are exposed to, prepare for, and make decisions about future careers in various non-academic sectors

Our findings showed the importance and impacts of PhD students' advisors on their professional development. Although students interested in academic careers received significant advice from their advisors for academic career paths, students not interested in academic careers largely did not receive any advice for non-academic careers. Furthermore, these students did not even feel comfortable mentioning their non-academic career interests because they perceived their advisors were not supportive of careers other than a tenure-track pathway [18]. Relatedly, we found that advising climate significantly positively relates to engineering PhD students' research skills, teamwork and project management skills, peer training and mentoring skills, and communication skills (as associated with primary funding mechanism; refer to [17], [20] for details). The climate around other people positively predicts different skills: faculty and staff climate was statistically significant for peer training and mentoring skills, and peer climate was statistically significant for both communication skills as well as peer training and mentoring skills [17]. However, the skills gained during students' master's and PhD programs don't always align with the skills needed for post-graduation careers, leading them to feel unprepared. In particular, recent graduates reported they wished they had better developed teamwork and cross-disciplinary collaboration skills [16].

RQ3: How engineering faculty/staff/administrators inform and prepare students for non-academic careers

An organizational-level approach [21] was useful for framing how master's and PhD programs can strategically prepare students for non-academic careers and considered in three influences:

1. Organizational characteristics such as proximity to local industry, institution size and reputation)
2. Management strategies such as structural measures, funding, and faculty incentives
3. Organizational culture such as working routines, long-standing norms, and mission/strategic plan

Following analysis of our interviews with 20 associate deans, staff, and faculty at 11 universities across the United States, we found that there is a spectrum of how deeply institutions leverage these categories [15]. At one end of the spectrum are institutions that consider only one of these categories, leaving graduate student professional development to individual faculty or lacking a cohesive strategy. On the other end of the spectrum are institutions that synergistically leverage all three of these categories, such as utilizing an industrial advisory council's feedback to design curricula that intentionally teach students skills needed for non-academic careers (cf. [15], Fig. 3). This publication includes several implications for practice, including how to support engineering graduate students' non-academic career preparation by building institutional support structures, establishing structured internship programs, and leveraging local engineers (individuals) and partners (companies, government laboratories).

Additional Findings

The Systems Approach for Better Education Results in Workforce Development (SABER-WfD) framework [22] considers skills in the labor market through an economic lens: there is supply (skills taught by engineering programs) and demand (skills needed in the workforce). In our paper "What engineering employers want: An analysis of technical and professional skills in engineering job advertisements" [12], we examined the "demand" side of technical and professional skills by mining 26,103 bachelor's-, master's, and PhD-level jobs in biomedical, civil, chemical, electrical, environmental, and mechanical engineering. We found that the most frequently sought technical skills across disciplines are Microsoft Office software and computer-aided design software. However, jobs with less-frequently requested skills, such as Python and MATLAB programming languages, commanded significantly higher salaries than jobs without those skills listed in the job posting. The most frequently sought professional skill was problem-solving. Findings from this study can help inform engineering educators to design curricula that prepare students to obtain and succeed in the engineering workforce after graduation. Findings can also help inform students which skills might result in higher salaries and, therefore, which skills they may want to prioritize developing during their studies.

3 | Outcomes: Practice

In addition to our research findings, this project has also compiled and produced resources for graduate students, staff, and faculty, all of which are available at our website. For graduate students, we developed a skills assessment tool, a five-minute survey asking them to rate their confidence in a variety of technical and professional skills. Following completion, students can download a report (Figure 1), which includes a snapshot of their responses, the full details of their responses, and a script for how to talk to their advisor or mentor about how to build skills necessary for their desired career during their graduate studies. For staff and faculty, we have developed a plug-and-play workshop with slides and facilitator notes that accompanies the graduate student skills assessment. The workshop, which lasts approximately one hour, probes students to consider the skills they already possess compared to skills needed for their desired career, how to use AI assistants to plan for their careers, and how to talk to their advisor or other mentors about building necessary skills during their graduate program.

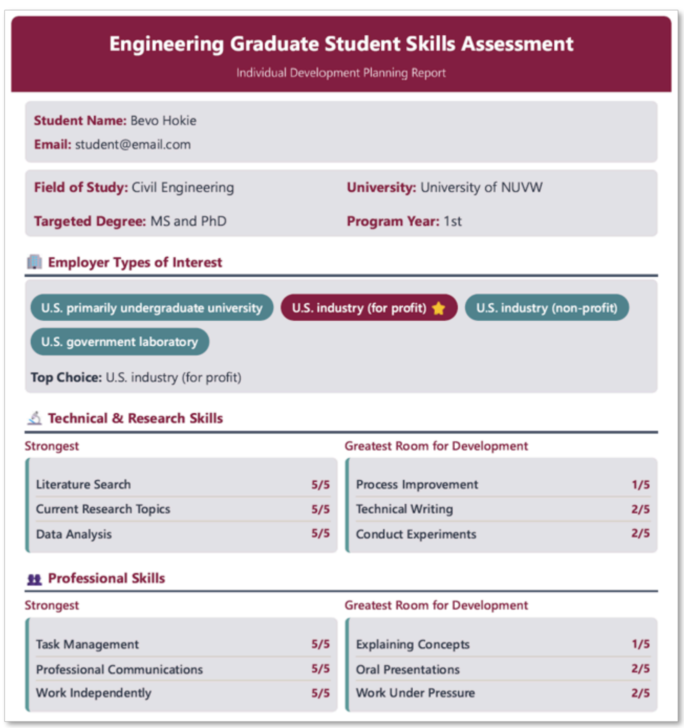

Figure 1. Preview of skills assessment report

The skills assessment was developed through a five-phase process. First, we developed an initial assessment using items from survey instruments for graduate student technical and professional skills. Topics included engineering and research competencies and interest [23], engineering competence [24], leadership skills [25], interdisciplinary competence [26], career interests [10], and transferable skills [27]. Second, we gathered qualitative feedback from different stakeholders: four faculty/administrators, one staff member, and one postdoc and three engineering education graduate students. Following this feedback, we reduced the assessment from 56 to 27 items. Third, we piloted the assessment with four graduate students. Graduate students represented a variety of engineering departments (biomedical engineering, civil engineering, computer science, and mechanical engineering), years in their programs, and targeted degrees (i.e., master's and PhD). We intentionally included non-native English speakers from outside the United States to obtain feedback on phrasing. In the fourth phase, we developed the online assessment tool and report. Finally, we piloted the tool with five PhD students and incorporated their feedback into the final versions of the assessment and report.

4 | Conclusions and Future Research

This project's findings demonstrate many facets of non-academic career preparation for engineering master's and PhD earners. At the student level (RQ2), we have shown the importance of individual students' advisors on their skill development and exposure to and preparation for non-academic careers. At the institutional level (RQ3), we found that there is a wide spectrum of how institutions prepare engineering graduate students for non-academic careers, and how institutions can proactively and synergistically leverage different factors to most effectively prepare students. Finally, on a systems level (RQ1), we have shown that the majority of students go on to non-academic careers, highlighting disciplinary differences in these rates and the skills students need to be job-ready. Our future research takes a more focused lens on examining career preparation for mechanical engineering master's students. Additional future research could include investigating how students chose their career paths to better understand how advisors and programs can support their needs.

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