AC 2011-2386: CHOICES FOR PH.D.S IN ENGINEERING: ANALYSES OF CAREER PATHS IN ACADEMIA AND INDUSTRY

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Choices for Ph.D.s in Engineering: Analyses of Career Paths in Academia and Industry

Abstract

Our study presents the career trajectories of engineering Ph.D.s from the perspectives of both industry and academia. In this report, we identified approximately 34 engineering Ph.D. graduates from U.S. programs who: (1) worked only in academia; (2) worked only in industry; (3) worked in academia first and now work in industry; or (4) worked in industry first and now work on academia. Using curricula vitae (CVs) as a main data source, we mapped out the detailed career trajectories of each participant. The comparisons within and across different groups characterized the particular career developmental models for each group. Both academia-only and industry-only groups demonstrate a relative linear developmental career path. However, it is notable that participants in the academia-only group tend to hold multiple appointments when compared to their industry-only peers. Participants from groups (3) and (4) showed much more complex career patterns than the first two groups. Also, all of our participants in the last two groups hold leadership positions currently. This observation emphasized the importance of leadership skills training for engineering Ph.D.s. Overall, this reports summarized pilot findings on career trajectories of engineering Ph.D.s. It provides unique insights for both the career planning of recent engineering Ph.D. graduates and the training and preparation of current engineering Ph.D.s.

Introduction

Engineering doctoral education encounters a variety of challenges as determined by policy makers, industrial professionals, and engineering doctoral students. These challenges relate to the students’ lack of training for jobs outside of academia, their abilities to adjust to change or to lead a change, and the narrow disciplinary training of graduate students. Considering the challenges facing engineering doctoral education, multiple initiatives have been launched to prepare engineering doctoral students for a changing society. These efforts include the emphasis of the translation of engineering education research to practice, the restructuring and design of a systematic engineering doctoral curriculum, the integration of project-, problem- or experiential-based learning into doctoral students’ educational activities and the piloting of global engineering program or co-op programs for the development of engineers’ global competencies. Recognizing the efforts of these initiatives, however, empirical studies are needed to understand educational outcomes and career trajectories of engineering doctoral graduates.

In 2008, the U.S. awarded over 48,800 doctorate degrees, with over 7,800 awarded in engineering fields. While the Ph.D. in engineering, like other fields, is traditionally seen as the start of a career in academe, engineering has seen dramatic shifts in the career trajectories of its graduate students over the past thirty years. In fact, recent data show that only 30% of engineering Ph.D. recipients choose to work at academic institution as faculties or researchers. The rest seek employment outside of academe.

The shift in professional placement has been accompanied by a change in primary work activities. At the end of the 20th century, teaching was still the most common post-graduation work activity
of Ph.D.s\textsuperscript{7}. Compared with 57\% of Ph.D.s from 1970-1974, only 37\% of Ph.D.s from 1995-1999 intended to spend most of their time teaching\textsuperscript{7}. Simultaneously, research and development increased as a primary work activity. In 1995-1999, 31\% of Ph.D.s with job commitments reported research and development as their primary work activity, up from 23\% in 1970-1974. The trend represents changes in academic and industrial employment. Further noted by Thurgood et al.\textsuperscript{7}, teaching declined as commitments in academe fell, and research and development rose along with commitments in industry. The trend from 1988 to 2008 has reported reductions in academe employment. The percentage of new doctorate recipients with definite employment commitments in industry or some form of self-employment in engineering increased from 54\% in 1988 to 73\% in 2008. The 19-percentage point gain in industry and self-employment in 2008 over 1988 was accompanied by declines of 16 percentage points in academe relative to 1988\textsuperscript{5}.

In an effort to understand more about the career paths of engineering Ph.D.s, the current study was designed and conducted. Using curricula vitae (CV) as a main data source, we mapped out the detailed career trajectories of all participants who graduated with engineering Ph.D.s and possessed different career trajectories. In this report, we identified approximately thirty-four engineering Ph.D. graduates from U.S. programs who: (1) worked only in academia; (2) worked only in industry; (3) worked in academia first and now work in industry; or (4) worked in industry first and now work on academia. We carefully documented all of their past positions since their completion of Ph.D. degrees. We compared within and across different groups concerning their career paths and transitions. Our findings show different patterns and characteristics of career trajectories under each group.

**Literature Review**

The economic development and standard of living in any given country are closely related to the scientific and technological advances generated locally. Doctoral education in science and engineering plays a critical role in fostering such development, as doctoral programs in these fields train highly skilled individuals who, following diverse career paths, contribute the productivity of their countries\textsuperscript{8}. Although public perceptions indicate that majority of doctorate holders pursue careers in academia, the “traditional segmentation of the research labor market where the doctorate was mainly valuable in the academic sector is losing ground” (p. 57)\textsuperscript{9}. Career choices for this group outside academia include the private sector, non-profit organizations, and government agencies, among others.

In the last decade, diverse studies have been conducted to characterize career paths of Ph.D.s in disciplines such as art history\textsuperscript{10}, social sciences\textsuperscript{11-12}, and engineering sciences\textsuperscript{13}. Traditional methods for conducting studies based on career analysis include the collection of qualitative data through interviews and/or questionnaires. Recently, the potential of using less obtrusive and less expensive methods to gather the necessary information to conduct this kind of studies has been explored. A group of researchers assessed the utility of the CV as a data source for examining the career paths of scientists and engineers as part of the Research Value Program of the School of Public Policy of the Georgia Institute of Technology\textsuperscript{14}.

Being an almost-universal type of document, the CV provides a rich source of information; it keeps chronological record of relevant professional and academic achievements and important
undertakings, portraying a longitudinal picture of someone’s career trajectory\(^{15-17}\). Diverse scholars have discussed the methodological issues related to the use of CV as data collection strategy, as well as the difficulties associated with the coding process of the documents\(^{14-15,18}\). Among those issues, we also find the lack of a standard format (e.g., different ordering of the information), potentially missing information, and varying length (e.g., short and long versions, or truncated versions) could compromise the data analysis process. As Dietz (2004) suggested, a CV’s structure and contents can be influenced by different contexts (institutional, sectional, or geographical); therefore, in order to make sense of the information gathered from different CV structures, on most occasions it is necessary to spend considerable time coding, checking, cleaning and reordering data\(^{14}\).

Despite the aforementioned limitations and issues, CVs poses unique features as the most complete longitudinal record of people’s careers\(^ {14}\). As Pirralha et al. (2009) explain, “the CV is a relatively easy document to get, displays an extended amount of information that would take a long time and money to gather otherwise and allows the return to the original source whenever required” (p. 4)\(^ {17}\). Through this relatively unobtrusive method, a plethora of longitudinal career analyses might be performed. A recent special issue of Research Evaluation, published in June 2009, compiles different examples of the state-of-the-art curriculum vitae method as to the theory and application of CV analysis.

**Methods**

**Participants**

Purposeful sampling was used to recruit engineering Ph.D.s. for this study. Via professional networks, we identified initially approximately more than 90 engineering Ph.D. graduates from U.S. programs who: (1) worked only in academia; (2) worked only in industry; (3) worked in academia first and now work in industry; or (4) worked in industry first and now work on academia. Thirty-four of these participants provided their CVs or have their full CVs available publicly online. A classification of this sample is presented in Table 1 based upon their industry or academic career paths, average number of years since obtaining their engineering Ph.D.s, and the range of years across participants.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Academia</th>
<th>Industry</th>
<th>Academia-Industry</th>
<th>Industry-Academia</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>14</td>
<td>12</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Average years after Ph.D.</td>
<td>9.5 yrs</td>
<td>8.5 yrs</td>
<td>20.5 yrs</td>
<td>20.4 yrs</td>
</tr>
<tr>
<td>Range of years after Ph.D.</td>
<td>3.5 - 20 yrs</td>
<td>1 - 25 yrs</td>
<td>14 - 25 yrs</td>
<td>13 - 26 yrs</td>
</tr>
</tbody>
</table>

Table 1. Basic information of participants, \( n=34 \).

It should be noted that in the process of grouping, positions in national labs, research centers, and non-profit organizations were counted as industrial positions instead of academic positions because of the structure of these positions. Unlike academic positions, which tend to have a standard ranking structure across organizations (e.g., Assistant Professor), positions in national labs and non-profit organizations resembled those found in industry.
Data Sources

Professional CVs provided by participants serve as our main source of data, since CVs represent personal advertisements in professional job searching and collaborations and provide a resource for an estimate of research productivity, research capacity, and social networking capacity. CVs are also useful in analyzing the career paths and the mobility of individuals.

For this study, 34 CVs were collected both via participants’ responses and an open internet search. Appropriate Institutional Review Board documents were approved. All identities were removed and pseudonyms were used throughout the report to protect the confidentiality of participants. As a study on career path, this report focuses on the analysis of professional experiences of the engineering Ph.D.s after their recipients of Ph.D. degrees. Professional experiences were documented in their CVs under subtitles such as, “Career History”, “Professional Experiences”, “Employment”, “Positions”, etc. Information under these sub-categories of CVs was the main sources for the analysis of their career trajectories. Other information under sub-categories such as “Education”, “Teaching Experiences”, “Community Service”, “Mentoring Experiences”, etc. was used as supplementary information for analysis. Career positions of participants listed on CVs as of December 2010 were included in the analysis.

Coding

A common coding scheme was used for all the collected CVs from four different groups - (1) Academia only (Ac); (2) Industry only (In); (3) Academia to industry (Ac-In); and (4) Industry to academia (In-Ac). For CV analysis, each CV was read and re-read by researchers to identify the relevant information for career trajectory analysis.

To analyze the participants’ career trajectories, each position was documented. Concurrent positions (e.g., both industry and academic appointments simultaneously) also were documented. When a participant held industrial positions and adjunct appointment in academia at the same time (e.g. adjunct assistant professor), his/her main position was then classified as industry. For each position, the type of position was also coded. A list of codes is shown in Table 2. A descriptive definition was provided for each position type for the consistency of coding. These codes were used to analyze the type position held by the participants.

<table>
<thead>
<tr>
<th>Category</th>
<th>Academia</th>
<th>Industry</th>
<th>Academia-Industry</th>
<th>Industry-Academia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codes</td>
<td>Postdoctoral</td>
<td>Engineer</td>
<td>Postdoctoral</td>
<td>Postdoctoral</td>
</tr>
<tr>
<td></td>
<td>Researcher</td>
<td>Manager</td>
<td>Researcher</td>
<td>Researcher</td>
</tr>
<tr>
<td></td>
<td>Professor</td>
<td>Leader</td>
<td>Professor</td>
<td>Professor</td>
</tr>
<tr>
<td></td>
<td>Leader</td>
<td></td>
<td>Engineer</td>
<td>Engineer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manager</td>
<td>Manager</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leader</td>
<td>Leader</td>
</tr>
</tbody>
</table>

Coding example:
Manager: A position where the person was responsible for managerial tasks;

Table 2: Major categories and coding
As a mapping of current status of our participants, table 3 provides the counts for each type of position under each group. For example, under the academy group, we have 11 participants holding professor positions, which range from assistant professor, associate professor to full professor. Another example, under the industry group, we have 7 participants holding engineer positions. These positions can be, “project engineer”, “senior engineer” and so on.

<table>
<thead>
<tr>
<th>Category (No.)</th>
<th>Academia (14)</th>
<th>Industry (12)</th>
<th>Academia-Industry (4)</th>
<th>Industry-Academia (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current positions (No.)</td>
<td>Professor (11)</td>
<td>Engineer (7)</td>
<td>Manager (1)</td>
<td>Leader (4)</td>
</tr>
<tr>
<td></td>
<td>Leader (3)*</td>
<td>Manager (1)</td>
<td>Leader (3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leader (4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* If the participants hold leadership positions, their professorship were not counted in this table

Table 3. Distribution of current positions for all participants

After the mapping of all career positions of all our participants since their recipients of Ph.D. degrees, these participants were checked carefully in terms of their career trajectories. As an example, the career trajectory of participant Dr. Smith (pseudonym) is shown in Figure 1 to illustrate the analysis procedure. Any concurrent positions (joint appointments) were omitted in this diagram. The documents of these career trajectories were compared. Themes were summarized from the comparison within and across different groups.

**Figure 1.** Career trajectory of Industry-Academia participant, Dr. Smith.
Results

Academia-Only Group

The structured promotion and tenure system in academia contributes to a relative linear career trajectory for this group. Seven out of fourteen participants in this group started their careers in academia at the Assistant Professor level. Five began as postdoctoral researchers, and two others started with a lecturer’s position before their appointments as Assistant Professor. The length of these researcher or lecturer positions ranged from several months to a couple of years. Six participants spent an average of 4.8 years in an Assistant Professor position before receiving tenure. The length of years in Assistant Professor positions ranges from three to eight years. Ten out of fourteen participants held one or more joint appointments at some points of their careers. Seven of the fourteen participants currently hold more than one position. Two of the participants are in the level of department head. Before their leadership positions, they were promoted from Assistant Professor to Full Professor. They served in professors’ position or other leadership position for 14 and 15 respectively. Although not currently a department head, another participant also held this position at one time in his career.

From these observations, career trajectories in academia are relatively linear-, starting with either a short period of research, a teaching appointment, or from an Assistant Professor position. Academic positions can allow professors to move to leadership positions after around 10 years of serving in their professorship. It should be pointed out that participants tend to have multiple appointments in academia (e.g., adjunct professorship, visiting professor position, or other teaching, research, or service-related appointments).

Industry-Only Group

Most of the participants from the industry group started with an engineering position except for one participant who started directly with a leadership position. Rankings and responsibilities of people in this group typically ranged from “Project Engineer” to “Senior Project Engineer” depending on the structure and company. This transition took place usually at around 1-3 years after their first positions. After another 1-3 years, they changed in their engineering titles and responsibilities and moved to a higher level. There were three participants who stayed in the same engineering position for 4, 5, and 10 years, respectively, without any change by the time their CVs were analyzed. Three of our participants moved from engineering positions to managerial positions after about six years in their engineering positions. Two of them moved from managerial positions to leadership positions after eight and ten years, respectively. Only three out of twelve participants presently hold joint positions.

The findings here suggest a relative linear career path for participants in the industry group. They typically started with an engineering position and moved to another engineering position with a higher rank and more responsibilities. Managerial positions could be the next step if such a transition happens. However, they could possibly stay in the engineering positions for more than five years without any change into managerial or leadership positions. Leadership positions could be the next step after managerial positions for participants in the industry group. One of the participants started directly with leadership position probably because of his intensive engineering internship experience before his receipt of the Ph.D.
Besides the linear characteristics in their career paths, the participants in the industry-only group also hold fewer joint appointments, especially when compared to their peers in the academia-only group. Only three participants out of twelve held joint appointments in their careers in this group. For the academia-only group, ten out of fourteen participants held more than one position at some time during their careers. These observations suggest the nature of flexibility in academic appointments compared to industry jobs and might explain the presence of multiple appointments in academia.

**Academia-to-Industry Group**

Although only four participants each were present in the last two groups, the career paths in both academia-to-industry and industry-to-academia groups demonstrate much more complexity than the former two groups. For the academia-to-industry group, the average working years after receipt of Ph.D. (20.5 years) are much longer than that of their peers in academia-only group (9.5 years) and industry-only group (8.5 years). All four of the participants held joint appointments when they were in academic appointments, two of them holding joint appointments in industry and the other two holding joint appointments in academia. Two participants still hold appointments as adjunct professors in academia while their main appointments are in industry. Participants spent 4, 8, 10, and 12 years, respectively, in academia before they transitioned to industry. All four of them started with engineering positions when they first transitioned from academia to industry. Many of the engineering positions represented titles such as “Senior Engineer” or “Senior Project Engineer.” They were different from the starting positions of participants in industry group. Three participants currently hold leadership positions in industry and the fourth participant holds a managerial position.

Overall, the career path of this group showed higher complexity than the former two groups. When the participants were in academia, all four of them held joint appointments either in academia or industry. This observation again suggests the flexibility of academic appointments. Their experiences in academia provided them with both the technical advantages (their initial higher rankings in industry) and the ties to academia for a joint appointment (adjunct professorship) after entering industry. All four of our participants presently hold some type of leadership of managerial positions. This observation emphasizes the importance of leadership skills for engineering Ph.D.s.

**Industry-to-Academia Group**

The average working years after Ph.D. receipt for the industry-to-academia group (20.4 years) is similar to that of the academia-to-industry group (20.5 years) and much longer than that of their peers in the academia-only group (9.5 years) and the industry-only group (8.5 years). In their time span in industry, they usually started with engineering positions similar to their peers in the industry group. Two participants moved to leadership positions before their transitions to academia. The other two participants were in research-related positions (“Scientific advisor” and “Researcher”) before their transitions to academia. Two participants held more than one position when they were in industry (adjunct professorship or other industrial appointments). Participants spent 2, 3.5, 6, and 8 years, respectively, in industry before their transitions to academia. Three participants started with assistant professorships after their transitions, and the other started
directly with full professor. All participants hold more than one position currently in academia. All of them hold both professorship and some leadership position at the same time. These joint appointments include, “Visiting Professor”, “Research Center Director”, “College Chair”, “Department Head”, etc.

Again, the overall trend of this group demonstrates much higher complexity than the academia-only and industry-only group. Also, the trend is very different from that of academia-to-industry group. The multiple appointments for all four participants (three of them holding three positions currently) suggest the high working load for faculty members in academia. Some of them held leadership positions before their transitions to academia suggest the pre-existence of leadership skills before their careers in academia. The current leadership positions further emphasized the importance of leadership skills for engineering Ph.D.s.

Discussion

In this report, we summarized the possible career trajectories under four major categories: (1) Academia-only (2) Industry-only (3) Academia-to-Industry; and (4) Industry-to-Academia. The first two groups each demonstrated a relatively linear career path. The Academia-only career path shows a linear path according to the standard path under promotion and tenure system. It first starts from a research or teaching position or directly from an assistant professor position. It then transits to associate professor and full professor positions. Interesting, the industry-only career path also showed linearity starting from engineering types of positions to managers and then leadership positions. The last two groups demonstrate much more complexities than the first two groups in terms of both the position types and transitions. Besides the four different career paths as discussed in results part, further indications are summarized as related to the career paths and attributes of engineering Ph.D.s.

First of all, participants in academia tend to hold multiple positions as shown in academia-only, industry-to-academia and academia-to-industry groups. These observations suggest the flexible nature of positions in academia and also the potentially high work load for faculty members. Flexibility has been listed as one of the reasons for which graduates choose academia career and could potentially allow a better balance of life and work. However, as suggested by our findings, the flexibility and the commitment to multiple appointments could also mean a high work load and the need to balance teaching, research, community service, and leadership responsibilities.

Most of participants held some type of leadership position at some time of their career across the four groups in our study. This observation highlights the significance of leadership in engineering Ph.D.s. Ph.D. holders are considered to be the leading force for knowledge-based economies. Multiple engineering educators have started to focus on the leadership qualities of engineering graduates. ABET criteria also listed leadership as one of the learning outcomes for engineering students. Our findings here emphasized the importance to promote leadership trainings in engineering graduate programs to facilitate their future career development.

Conclusion

Multiple career trajectories and their characteristics were summarized in this report. These findings and implications provide initial understanding about the career trajectories and the
attributes of engineering Ph.D.s. It should be noted that we identified our participants by grouping them into pre-defined four groups; however, there are certainly other types of career paths besides the four groups analyzed here. In our search for different participants, we also identified other participants who concurrently worked in both industry and academia. The underlying reasons and related implications could provide further insights to the analyses of engineering Ph.D. career paths for our future studies. Future studies for career trajectories analyses may also incorporate the consideration of gender differences, the difference in ethnicity and nationality. Also, the differences between careers in industry, national labs, and non-profit organizations need more investigations.

Studies on career trajectory provide insights for engineering Ph.D.s’ career options and the current training of engineering Ph.D.s. It offers insights as to career planning and job searching for recent Ph.D.s graduates who are ready to start a new career. Meanwhile, research on career trajectories and the attributes of engineering Ph.D.s provide feedback to our current graduate education systems as to the key knowledge, skills and attributes that are required of engineering Ph.D.s.

Acknowledgements

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