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# Curriculum Vitae Analyses of Engineering Ph.D.s Working in Academia and Industry*

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In recent years there have been discussions surrounding the under-preparedness of Ph.D. graduates of highly specialized doctoral programs, lacking interdisciplinary focus and professional skill development, to succeed in future complex work environments. To address these concerns, Golde and Walker suggest re-conceptualizing doctoral education such that Ph.D. holders are developed as "stewards" of their disciplines. To provide initial insights into how engineering can be viewed through a stewardship lens, the authors conducted a content analysis of thirty-six curricula vitae of engineering Ph.D. holders who have been employed in one of four occupational sectors- (1) academia only, (2) industry only, (3) academia and then industry, or (4) industry and then academia. This effort seeks to operationalize their experiences into the three tenants of the stewardship framework—generation, conservation and transformation—and provide a new perspective for future discussions around the preparation and expectations of engineering Ph.D. holders. Industry participants reported higher generation and conservation than academia only participants; academia to industry participants reported higher instances of generation followed by conservation; industry to academia participants, on average, reported higher generation; and a new category, "other," was the lowest instance across all groups.

**Keywords:** curricula vitae; stewardship; doctoral education; engineering professionals

## 1. Introduction

The history of doctoral education in the U.S. is unique, and, as a result, has attracted talented students from around the world to study in U.S. universities. Recent developments in graduate education (e.g., the increased involvement of China, India, Australia, the United Kingdom, and Canada in graduate education initiatives) indicate that U.S. higher education institutions might face considerable competition in the recruitment of talented doctoral candidates. Within the past ten years, researchers and practitioners have explored doctoral education and are advising higher education institutions to revisit the attitudes and the attributes of their doctoral recipients along with challenges to doctoral degree completion [1, 2]. Additionally, authors point to the narrow and highly specialized disciplinary focus of graduate programs; a lack of interdisciplinary work within these programs; and an absence or lack of development of doctoral students' professional skills, which are needed to function successfully in future work environments. Moreover, scholars point to the under preparedness of doctoral students for positions within the academy as researchers and teachers and an inability for Ph.D. graduates to recognize and to manage technical and social changes [3–5]. These trends in doctoral education are alarming given the increasing demand for engineering Ph.D. holders in and out of the academy to work on interdisciplinary teams and in a variety of complex environments. In an attempt to address these trends, Golde and Walker suggest re-conceptualizing doctoral education such that Ph.D. holders become "stewards" of their disciplines [5].

Engineering is a diverse field with multiple career options for Ph.D. holders. In 2010, approximately 51% of engineering Ph.D. recipients in the United States were foreign-born [6]. Within engineering, the number of Ph.D. recipients entering industry versus academia continues to increase, with the majority of engineering Ph.D. recipients reporting their intentions to work in industry [7]. In 2003, 47% of all Ph.D. recipients in science and engineering were employed at educational institutions, 6% were self-employed, and the remaining 47% worked within government and private sectors [8]. Of recent graduates with engineering doctoral degrees and definite post-graduation U.S. employment commitments, the majority secure careers in industry (64.4% in 2010 compared to 16.9% in academia

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[6]). Although recent literature has reported geographic trends among engineering Ph.D. recipients [7], the desired skills and attributes expected of engineers [9, 10], and doctoral graduates' career preferences [11], limited research has explored the experiences and characteristics of engineering Ph.D. holders via curricula vitae (CV) analyses. In addition, although studies have explored the expectations of industry for engineering undergraduates [12, 13] and of engineering doctoral students [14] and have presented a case for exploring alternative pathways for engineering Ph.D. holders [15], few studies have grounded their work in existing theoretical frameworks.

In an effort to connect engineering professional practices of engineering Ph.D. holders in academia and industry to a larger conversation within higher education about the preparation of doctoral students, authors have selected Golde and Walker's stewardship framework [5]. Reviewing, coding, and analyzing the experiences of thirty-six engineering professionals in academia and industry using CVs and framing this work within the three tenets of Golde and Walker's stewardship framework, this paper will operationalize the experiences of engineering Ph.D. holders who are working in a variety of fields. Since this concept of stewardship has not been explored extensively among engineering populations, this work has the potential to provide insight into the operationalization of stewardship among doctoral engineers working in both academic and industrial settings.

## 2. Literature review

### *2.1 Theoretical framework: Stewardship*

The framework selected for this study is stewardship by Golde and Walker [5]. Supported by the Carnegie Initiative on the Doctorate, stewardship defines the role of Ph.D. holders and the purpose of doctoral education. According to Golde and Walker, a Ph.D. holder is a steward of one's discipline as demonstrated via technical competence, strong ethics, and abilities to apply knowledge to global problems that benefit their disciplines and society. They acknowledged that the operationalization of stewardship will vary across disciplines and conducted an initial exploration of stewardship across six disciplines—chemistry, education, English, history, mathematics, and neuroscience. Stewardship extends to current and future scholars and is represented by three facets: (1) generation, (2) conservation, and (3) transformation (Table 1). Twenty-first century engineering education goals align closely with the tenets of stewardship, since the attributes of Ph.D. engineers include abilities to develop high quality technical knowledge (similar to generation), to determine how disciplinary knowledge aligns with the larger context of knowing and understanding (similar to conservation), and to comprehend how to teach the next generation of engineers and prepare them for future engineering work (similar to transformation) [15, 16].

Despite this alignment, it is important to determine how activities, skills, tasks or services completed by engineering Ph.D. holders in academia and industry contribute to ideas of stewardship. Given the complexities of engineering (e.g., multiple disciplines and career paths), engineering roles framed within the context of stewardship and examined via CV snapshots might provide a model for future operationalization of stewardship across other engineering contexts, might allow researchers to view engineers' career development over time, and might lay a foundation for deeper conversations about the presence or absence of generation, conservation, and transformation among engineering professionals.

### *2.2 The preparation and expectations of engineering Ph.D.s*

Multiple researchers have identified the core competencies or characteristics of engineering Ph.D. recipients over the past several decades [17–21].

**Table 1.** Dimensions of stewardship as adapted from Golde & Walker [5]

| Dimensions | Definitions | Manifestations |
|---|---|---|
| **Generation** | Creating new knowledge, defending this knowledge from challenges and criticism, and expanding disciplinary boundaries. | • Ask interesting and important questions.<br>• Formulate appropriate strategies for investigating these questions.<br>• Conduct investigations with technical competence.<br>• Analyze and evaluate results of the investigations. |
| **Conservation** | Conserving ideas, knowledge, or skills that contribute to the larger field. | • Comprehend the fundamental ideas and history of the discipline.<br>• Acknowledge research predecessors.<br>• Evaluate ideas that are worth keeping and have outlived their usefulness.<br>• Situate discipline into the larger intellectual landscape. |
| **Transformation** | Translating knowledge to a variety of audiences both formally and informally. | • Communicate knowledge and ideas effectively across traditional boundaries.<br>• "Teach" formally and informally.<br>• Recognize the multidisciplinary aspect of differences. |

Some of this research focuses on the core roles and responsibilities of graduate students as future engineering faculty along with different ways to prepare students for academic careers [18, 22, 23]. Others emphasized the critical skills, characteristics, and possible strategies that are essential for graduate students to be successful in industrial settings [17, 21]. In addition, Cox et al. [23] discussed the role of graduate education in preparing engineering students for the core competencies. These studies have added to current understanding about the essence of doctoral education, particularly within engineering.

Watson and Lyons [21] identified a list of the skills and attributes that are most relevant to engineering Ph.D. recipients who enter industry. Their survey, completed by 109 working professionals with engineering Ph.D. degrees from small business and corporate groups, noted relevant skills and attributes among graduates to include problem-solving skills, teamwork skills, and oral and written communication skills. Based on additional open-ended questions, they reported the importance for engineering Ph.D. holders to comprehend and to adapt to their industrial working environments.

Some of these skills also are reflected in a qualitative study conducted by Cox et al. [20] among eleven working professionals in academia and industry. From semi-structured interviews, they found desired industry skills for engineering Ph.D. holders to include teamwork, leadership, communication, and business management and the desired skills for engineering Ph.D. holders working in academia to include funding knowledge, conducting research, teaching, and publishing. Additional skills and attributes relevant to all engineering Ph.D. recipients relate to technical communication [17], strong analytical skills [20], and financial skills [19]. This pilot study informed the development of the current study among thirty-six engineering professionals with Ph.D.s.

In addition to the critical skills or attributes that have been identified by multiple researchers, other researchers and educators have explored different strategies that might prepare engineering graduate students for various careers. Austin [18, 24] pointed out that some of the major challenges facing future faculty members include the diversity of student and faculty populations, the rise of the latest information technologies and their potential applications in educational technology, the constraints of limited funding, and an increasing focus on the learning outcomes of students. She created a list of suggestions in preparing future faculty, which included learning to communicate with multiple audiences, learning to work in diverse group settings, understanding engagement and service, and adopting technology to advance education.

## 3. Methods

### *3.1 Data collection*

This study is part of a larger study on the application of the stewardship framework in understanding engineering Ph.D. recipients from different sectors using curricula vitae (CVs) and one-on-one interviews. CVs were requested from participants prior to interviewing them about their experiences as engineering Ph.D. holders. No formal guidelines were presented to participants about the expected length of CVs, CV content, or CV format, and as a result, CVs ranged from one to eighty pages. CVs were classified according to participants' years of experience and occupational sector.

CVs were chosen as artifacts to analyze the operationalization of the stewardship framework since a CV is a prevalent and relatively standardized document that summarizes academic, professional, and other accomplishments, and since, within engineering and science fields, CVs have been identified as excellent standalones and complementary sources of data [25]. In a comprehensive survey of the CV method for science policy and research evaluation since the 1990s, Cañibano & Bozeman [26] note that CV analyses have focused primarily on career trajectories, mobility, and mapping of collective capacity. Cox et al. [27] have used this method to explore the career trajectories and leadership roles of engineering Ph.D. recipients in academia and industry (with an emphasis on gender), and Dietz et al. [25] utilize a "knowledge value model" to explore the career paths of scientists and engineers via CVs' longitudinal data.

Challenges and limitations of using CVs as a data source are also recognized. Among the criticisms include variability in the availability, format, length, and structure of the CVs. Other criticisms include the questionable integrity of self-reported information, missing information, and the time-consuming process of CV coding [25, 26]. Despite these challenges, Dietz et al. [25] note that the use of CVs as a research tool is promising. In light of anticipated coding issues, it is imperative that well-defined research questions and targets are developed to focus attention on appropriate variables within CVs [26].

For this reason, the research question of interest within this study asks, "How do the activities of engineering Ph.D. holders (obtained via CVs) align with the tenets of the Golde and Walker's [5] stewardship framework?"

### *3.2 Participants*

Thirty-six participants within this study consented to participation as part of a larger study in which they were interviewed about their motivations for pursuing a Ph.D., their employers' expectations of them as Ph.D. holders, and what it means to be an engineering professional with a Ph.D. within the sector in which they worked. Basic demographics include the following: gender (twenty-five males and eleven females), nationality (thirty U.S. born/ domestic and six non U.S. /international), years of experience (nine with less than 5 years of experience, eight with 5–10 years of experience, fourteen with 10–20 years of experience, and five with more than 20 years of experience), and occupational sector (fifteen worked in academia only, ten worked in industry only, four worked in academia first and now industry, and seven worked in industry first and now in academia).

Tables 2–5 display participants' demographics for each of the four occupational sectors. Note that the ID classification represents the *sector* ("A" for academia only, "I" for industry only, "AI" for academia to industry, and "IA" for industry to academia) followed by the *level of experience* ("1" represents less than 5 years of experience, "2" represents 5 to 10 years of experience, "3" represents 10 to 20 years of experience, and "4" represents more than 20 years of experience), and the participant number for each occupational sector. Using this classification, an ID of "A1-1" means that the participant worked in academia for less than five years and is coded as the first participant in this sector. Within academia, institutions are classified based upon the U.S. Carnegie institutional classifications, and within industry, companies are classified according to Fortune 500 America's corporate classifications for 2012. The *engineering fields* represented within this study include aerospace engineering (AE), biomedical engineering (BME), chemical engineering (ChemE), electrical and/or computer engineering (ECE or EE), industrial engineering (IE), materials science and engineering (MSE), and mechanical engineering (ME).

The current positions of participants working within academia and industry did not fit neatly into traditional categories. While the majority of academicians held positions as Assistant Professors, Associate Professors, or Full Professors, academia only participants also held non tenure-track positions such as lecturer, research associate, adjunct professor, and consultant along with administrative positions such as department chair and vice president. For participants who worked in industry and then academia, roles were more

**Table 2.** Demographics of participants who have only worked in academia post-Ph.D.

| ID | Gender | Field | Status | # Yrs | Recent Position | Institution's Carnegie Classification |
|---|---|---|---|---|---|---|
| A1-1 | F | ME | Domestic | < 5 | Assistant Professor | Baccalaureate College-Diverse Fields |
| A1-2 | M | ECE | Domestic | < 5 | Assistant Professor | Master's College and University (larger programs) |
| A1-3 | F | ChemE | Domestic | < 5 | Lecturer | Research University (very high research activity) |
| A1-4 | M | AE | Domestic | < 5 | Assistant Professor | Master's College and University (medium programs) |
| A2-1 | M | ME & AE | International | 5 to 10 | Assistant Professor | Research University (very high research activity) |
| A2-2 | M | ME | Domestic | 5 to 10 | Research Associate, Lecturer | Research University (very high research activity) |
| A2-3 | F | EE | Domestic | 5 to 10 | Assistant Professor | Master's College and University (smaller programs) |
| A2-4 | F | ECE | Domestic | 5 to 10 | Assistant Professor | Special Focus Institutions—Schools of engineering |
| A2-5 | F | MSE | International | 5 to 10 | Assistant Professor | Research University (very high research activity) |
| A3-1 | F | ME | Domestic | 10 to 20 | Lecturer; Outreach Director | Doctoral/Research University |
| A3-2 | M | ME | Domestic | 10 to 20 | Professor | Master's College and University (larger programs) |
| A3-3 | M | EE | Domestic | 10 to 20 | V.P. of Higher Education Policy | Doctoral/Research University |
| A3-4 | M | BME | Domestic | 10 to 20 | Adjunct Assistant Professor | Research Laboratory (non Carnegie) |
| A3-5 | F | ChemE | Domestic | 10 to 20 | Associate Professor | Research University (very high research activity) |
| A4-1 | M | ECE | Domestic | > 20 | Professor & Department Chair | Research University (very high research activity) |

**Table 3.** Demographics of participants who have only worked in industry post-Ph.D.3

| ID | Gender | Field | Status | # Years | Recent Position | Company's Classification |
|---|---|---|---|---|---|---|
| I1-1 | M | ChemE | International | < 5 | Mechanical Engineer | Household and Personal Products (Ranked between 101 to 150) |
| I1-2 | M | ECE | Domestic | < 5 | Software Engineer | Internet Services and Retailing (Ranked between 50 to 100) |
| I1-3 | M | IE | Domestic | < 5 | Professional Training Director | Aerospace and Defense |
| I1-4 | F | BME | Domestic | < 5 | Systems Design Engineer | Ranked outside Fortune 500 Classification |
| I1-5 | F | ChemE | Domestic | < 5 | Scientist | Household and Personal Products (Ranked between 101 to 150) |
| I2-1 | M | ME | International | 5 to 10 | Mechanical Engineer | Household and Personal Products (Ranked between 101 to 150) |
| I2-2 | F | ChemE | Domestic | 5 to 10 | Engineer Associate | Petroleum Refining (Ranked between 1 to 50) |
| I3-1 | M | IE | Domestic | 10 to 20 | Senior Manager | Mail, Package, and Freight Delivery (Ranked between 50 to 100) |
| I4-1 | M | ChemE | Domestic | > 20 | Director, Research and Development | Chemicals (Ranked between 201 to 250) |
| I4-2 | M | ChemE | Domestic | > 20 | Director, Process Engineering | Network and Other Communications Equipment (Ranked between 301 to 350) |

**Table 4.** Demographics of participants who worked in academia then industry post-Ph.D.

| ID | Gender | Field | Status | # Years (AC/IN) | Recent Position | Current Company's Classification |
|---|---|---|---|---|---|---|
| AI2-1 | M | EE | International | 10–20 | Chief Technology Officer | Renewable energy technology sector |
| AI2-2 | M | EE | International | 10–20 | Director | Department of Engineering & Technology |
| AI2-3 | M | ME | Domestic | 10–20 | Principal Engineer | Construction and Farm Machinery (Ranked between 51 to 100) |
| AI2-4 | M | ME | Domestic | 10–20 | Engineering Technical Steward | Construction and Farm Machinery (Ranked between 1 to 50) |

**Table 5.** Demographics of participants who worked in industry then academia post-Ph.D.

| ID | Gender | Field | Status | # Years (IN/AC) | Recent Position | Current Institution's Carnegie Classification |
|---|---|---|---|---|---|---|
| IA2-1 | M | ChemE | Domestic | 5–10 | Postdoctoral Fellow | Master's College and University (larger programs) |
| IA3-1 | F | ECE | Domestic | 10–20 | Assistant Professor | Research University (very high research activity) |
| IA3-2 | M | ChemE | Domestic | 10–20 | Department Chair | Associate's—Public 4-year Primarily Associate's |
| IA3-3 | M | MSE | Domestic | 10–20 | Associate Chair | Research University (very high research activity) |
| IA3-4 | M | ChemE | Domestic | 10–20 | Professor | Research University (very high research activity) |
| IA4-1 | M | ECE | Domestic | >20 | Distinguished Professor | Research University (very high research activity) |
| IA4-2 | M | ChemE | Domestic | > 20 | Founder<br>Sr. Lecturer | Science Consulting Service<br>Research University (very high research activity) |

administrative in nature and related closely to leadership positions. Industry only participants with less than five years of experience mostly held positions as engineers or scientists, while those with senior experience were directors and managers within their companies. Of the four academia to industry participants, roles varied greatly and represented both administrative and technical roles.

### 3.3 Data analysis

Content analysis was applied in the analysis of participants' CVs [28]. Initial definitions for generation, conservation, and transformation were developed *a priori* [29] based upon the definitions in Golde and Walker [5]. Using these definitions, two researchers coded two CVs and developed the first version of codebook. Sample codes at the first level (i.e., generation, conservation, and transformation) and at the second level include the following:

- *Generation* (Awards and honors; Grants and contracts as a principal investigator; Grants and contracts as a co-principal investigator; Authorship)
- *Conservation* (Journal or conference paper referee; Supervision of students; Membership in professional societies or organizations (national or regional); Professional societies or organization (local organization))
- *Transformation* (Commercialization, Panelist, Guest or keynote speaker, Patents, Presentations, or Posters)

In addition to these tenets, researchers created codes that were classified as "Other." Such codes included items that did not align explicitly with the definition of stewardship or did not reflect "stewardship within the discipline" (e.g., professional development).

After we created the first version of the codebook, we discussed among six researchers possible modifications to the codebook (such as the differentiation between authorship positions across engineering disciplines). An additional CV was analyzed and coded to finalize the codebook.

### 3.4 Inter-rater reliability check

As the primary goal of this study is to operationalize the three tenets of stewardship, reliability across coders was identified to be a priority. The codebook was applied to two CVs for inter-rater reliability checks. Cohen's Kappa was used to calculate reliability across coders, since it measures the percentage of agreement between raters that is beyond purely chance agreement [30]. A Cohen's Kappa of 94% was calculated between coders (81–100% is deemed to be nearly perfect) [30, p. 124]. Remaining CVs were coded using Atlas.ti Version 7, and patterns and themes were summarized across the four sectors (academia, industry, academia to industry, and industry to academia) and across the years of experience after receipt of an engineering Ph.D. (i.e., less than 5 years, 5–10 years, 10–20 years, or more than 20 years). Results of the analysis follow.

## 4. Results

### 4.1 Trends across groups

Since the length of CVs varied across participants, percentages of occurrence of stewardship were reported instead of frequencies. Within this section are tables presenting the instances of stewardship for professionals working in each of the four occupational sectors.

Authors found that for professionals working in industry only, the highest stewardship occurrence, on average, related to generation followed by transformation (Table 6). Trends show, however, that instances of stewardship are not directly proportional to years of experience.

Among participants who have worked only in academia, instances of generation and conservation were higher on average than instances of transformation (Table 7). Similar to the findings among industry only participants, instances of stewardship are not directly proportional to years of experience.

Since fewer participants with experiences in academia and then industry self-selected to participate in this study, CVs were available only for academia to industry participants with 10 to 20 years of experience and with more than 20 years of experience. CV analyses confirmed that the majority of instances

**Table 6.** Overall percentages of stewardship and "Other" across industry only participants

| | | Generation | Conservation | Transformation | Other |
|---|---|---|---|---|---|
| **Industry** | <5 | 58% | 26% | 12% | 4% |
| | 5–10 yrs | 47% | 16% | 37% | 0% |
| | 10–20 yrs | 75% | 0% | 25% | 0% |
| | 20+ | 63% | 10% | 17% | 10% |

**Table 7.** Overall percentages of stewardship and "Other" across academia only participants

| | | Generation | Conservation | Transformation | Other |
|---|---|---|---|---|---|
| **Academia** | <5 | 29% | 41% | 23% | 7% |
| | 5–10 yrs | 30% | 39% | 27% | 4% |
| | 10–20 yrs | 41% | 31% | 27% | 1% |
| | 20+ | 58% | 18% | 22% | 2% |

**Table 8.** Overall percentages of stewardship and "Other" across academia to industry participants

| | | Generation | Conservation | Transformation | Other |
|---|---|---|---|---|---|
| **Academia to Industry*** | 10–20 yrs | 74% | 20% | 5% | 1% |
| | 20+ | 47% | 45% | 7% | 1% |
| | Average | 61% | 33% | 6% | 1% |

* Note that no academia to industry participants had less than 5 years or 5–10 years of experience.

**Table 9.** Overall percentages of stewardship and "Other" industry to academia participants

| | | Generation | Conservation | Transformation | Other |
|---|---|---|---|---|---|
| **Industry to Academia*** | <5 | 31% | 23% | 46% | 0% |
| | 10–20 yrs | 38% | 35% | 25% | 2% |
| | 20+ | 66% | 21% | 13% | 0% |

* Note that no industry to academia participants had <5 years or 5–10 years of experience.

for this group related to generation, conservation, and transformation, respectively (Table 8).

In the same way that fewer participants from academia to industry self-selected to participate in the study, participants with experiences in industry first and then academia represented all but one experience group (i.e., 5–10 years) within this study. Among the remaining CVs analyzed for this occupational sector, researchers found that the groups representing more than 10 years of experience reported the most instances of generation and conservation, respectively (Table 9). On the other hand, transformation and generation were found to be most prevalent within the group with less than five years of experience.

Across all groups, "other" is classified lowest, meaning that the majority of content within the CVs fit into the stewardship framework as coded by researchers.

In an effort to determine why the group trends within Tables 6–9 were reported, authors created stacked bar graphs reporting the individual instances of stewardship identified within participants' CVs. The graphs, grouped by occupational sector and by years of experience, provide a basis for additional elaboration about CV content that reflects the stewardship framework. Participants' identification codes can be mapped to Tables 2–5 in an effort to map table information to demographics.

### *4.2 Trends across engineering Ph.D. holders in academia only*

This section presents the manifestation of stewardship framework among four experience groups from academia: (1) less than 5 years, (2) 5–10 years, (3) 10–20 years, and (4) more than 20 years. Within the following discussion of each group, we presented a figure that summarizes the individual instances of generation, conservation, and transformation along with other codes within the CV analysis that did not align with the disciplinary aspects of the stewardship framework. We then discussed the typical cases within each group across participants.

#### *4.2.1 Less than five years*

Across this group, conservation is the most frequently occurring tenet of stewardship (Fig. 1). This is not surprising, however, since all but one of the professionals with less than five years of academic experience after receipt of the Ph.D. do not work at research intensive universities. The one professional working at a research university, A1-3, is a lecturer, a position that does not necessarily require high engagement with research, or generation, as framed within the context of stewardship. A1-1 works at a baccalaureate university and A1-2 and A1-4 both work at primarily Master's universities. Approximately one-third of A1-4's activities represent something other than stewardship.

To provide additional insight about the trends presented in Fig. 1, examples of stewardship codes within CVs are provided below for participants A1-1 (largest instance of conservation within this group) and A1-4 (largest instance of other within this group). A1-1 reported the highest instance of conservation within this group and spent the majority of her time within conservation, teaching undergraduate courses ranging from the freshmen to the senior level, serving as a faculty advisor for the departmental newsletter, serving on a Visiting Fellows Committee, engaging in recruitment and outreach activities, and organizing exam review sessions. A1-4, an Assistant Professor at a master's college and university, reported the highest percentage of instances of "other" within this group. Over half of the activities within this category reflect his

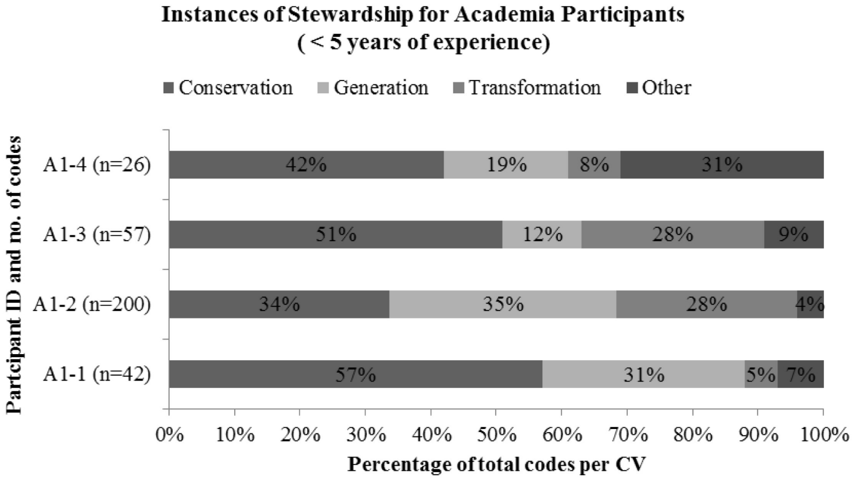


**Fig. 1.** Percentage of instances of conservation, generation, and transformation for academicians with less than five years of experience.

participation in community and volunteer programs and engagement in the design and leading of a personal finance class. He also attended numerous workshops to support student teaching, multidisciplinary seminars, and conferences.

### 4.2.2 *Between five to ten years*

The activities of academia only participants with experience between five and ten years align closely with the traditional tenets of stewardship (Fig. 2). Only A2-1 and A2-4 demonstrate activities that do not represent stewardship, although in small amounts (i.e., 3% and 11%, respectively). A2-1, A2-2, and A2-3 report large instances of generation and transformation, and A2-4 and A2-5 report more instances of conservation than generation and transformation.

To provide additional insight about the trends presented in Fig. 2, examples of stewardship codes within CVs are provided below for participants A2-2 (largest instance of transformation within this group), A2-3 (largest instance of generation within this group), and A2-4 (most balanced across all categories within this group). The majority of the transformation activities for A2-2, who is a Research Associate and Lecturer, included presentations of disciplinary research, including presentation of papers, at conferences and workshops and

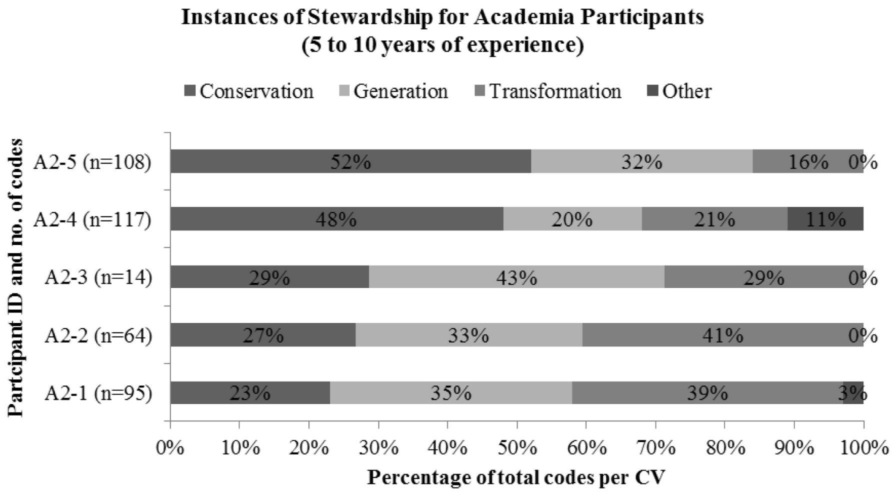


**Fig. 2.** Percentage of instances of conservation, generation, and transformation for academicians with five to ten years of experience.

serving as an invited seminar/speaker at conferences and universities in the U.S. and abroad. A2-3's generation activities included journal publications and a conference proceeding along with A2-3's role as an Honorary Fellow and engagement in international research collaborations. A2-4, an Assistant Professor at a school that primarily targets engineering students, demonstrated a very balanced profile. Among the "other" content presented within her CV included engagement in engineering professional development activities and workshop participation at conferences.

*4.2.3 Between ten to twenty years*

The activities of engineering professionals who have only worked within academia and have eleven to twenty years of experience demonstrate activities that align closely with the tenets of stewardship (Fig. 3). Within this group, A3-1, A3-2, and A3-4 report activities that are not aligned with stewardship. Both A3-1 and A3-2 demonstrate large instances of generation and transformation with A3-1 and A3-4 demonstrating over 50% of activities related to generation (53% and 65%, respectively).

From the CVs for participants within this group, A3-2 reported the largest instance of transformation, A3-4 reported the largest instance of generation, and A3-5 displayed the most balanced instances of stewardship and "other" across all categories. A3-2's transformation activities mostly include conference and symposium presentations of disciplinary research and serving as a contributing member of professional organization and as an academic advisor for competitive student teams. Unlike the other participants in this group, A3-4 works as an Adjunct Assistant Professor at research laboratory. This role, focused primarily on research production, is confirmed since the majority of A3-4's generation activities are a result of his prolific publishing efforts in journals and books (100 total publications) and grant writing. Finally, A3-5, who is an Associate Professor at a research university, reports 35 publications (generation), supervision of 45 undergraduate students, Master's students, doctoral students, and postdoctoral researchers (conservation), guest lectures and seminars in the U.S. and abroad along with course redesign (transformation), and service on academic boards and a laboratory renovation ("other").

*4.2.4 Greater than twenty years*

The one engineering professional with more than twenty years of experience working only in academia demonstrated the largest amount of generation followed by transformation and conservation (Fig. 4).

This professional demonstrated proficiency as a scholar and as an administrator. Generation activities included over 250 academic publications in his discipline and in STEM education with 13% of these as first author. Conservation activities included his supervision of almost 20 doctoral students. Transformation efforts included presentations and keynotes to increase the representation of minorities in STEM across the educational continuum (i.e., middle school to graduate school). Representations of "other" activities include awards and engagement in activities that do not fit align neatly into traditional disciplinary awards and activities (e.g., serving on the Board of non-engineering organizations).

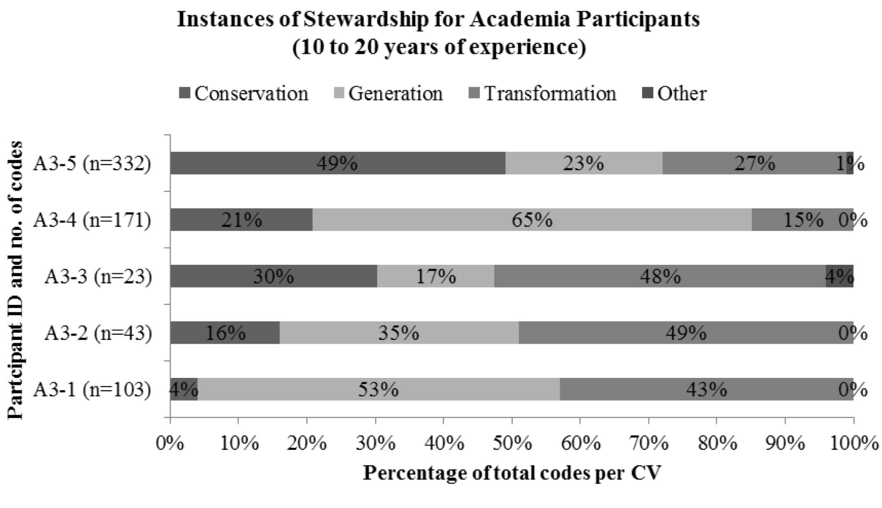


**Fig. 3.** Percentage of instances of conservation, generation, and transformation for academicians with ten to twenty years of experience.

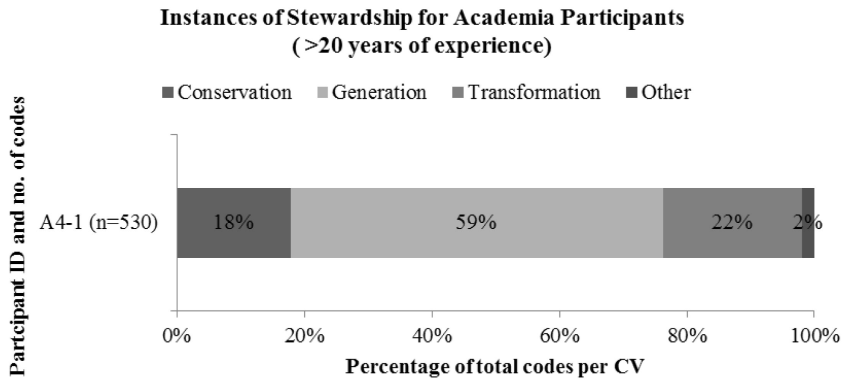


**Fig. 4.** Percentage of instances of conservation, generation, and transformation for academicians with greater than twenty years of experience.

### *4.3 Trends across participants working in industry only*

This section presents the manifestation of the stewardship framework among four experience groups from industry ((1) less than 5 years, (2) 5–10 years, (3) 10–20 years, and (4) more than 20 years). We present a figure for each group that summarizes the individual instances of generation, conservation, and transformation along with other codes within the CV analysis that did not align with the disciplinary aspects of the stewardship framework. We then discussed the typical cases within each group across participants.

#### *4.3.1 Less than five years*

For participants with less than five years working in industry, three out of five participants (I1-1, I1-2, and I1-5) demonstrated more instances of generation than the other two stewardship tenets (Fig. 5). I1-3 has a higher representation of transformation than other participants. I1-4 shows the highest representation of conservation across the five participants.

The instances in generation for I1-1 and I1-2 result mostly from external and internal publications. For I1-5, job experiences such as product or technology development are aligned closely with generation. The high instances of I1-3 in transformation result from his experiences serving as a consultant or guest speaker at outreach events. This makes sense since I1-3 is a Professional Training Director. I1-4 showed more instances of conservation mostly because of his involvement in professional disciplinary organizations.

#### *4.3.2 Between five to ten years*

Only two participants in our sample, I2-1 and I2-2, have 5 to 10 years of industry experience. I2-1

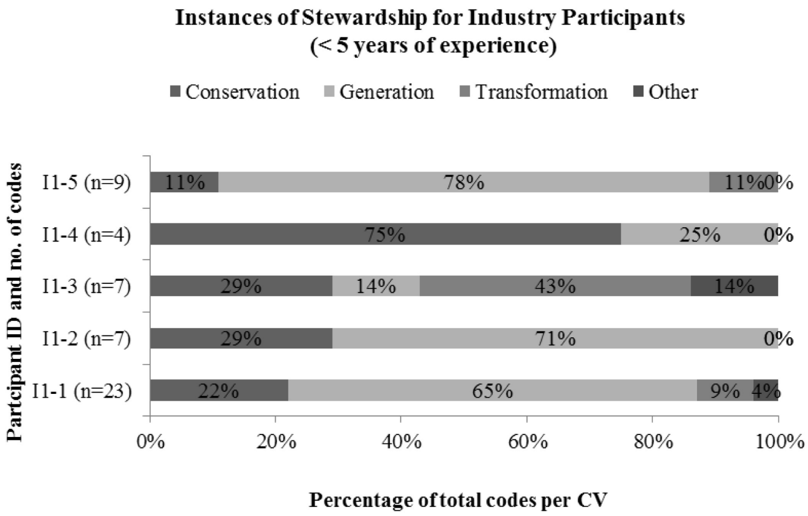


**Fig. 5.** Percentage of instances of conservation, generation, and transformation for industry professionals with less than five years of experience.

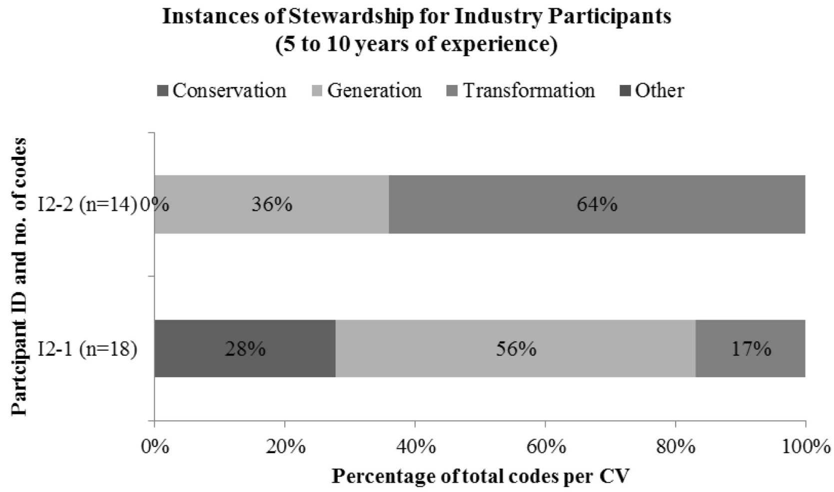


**Fig. 6.** Percentage of instances of conservation, generation, and transformation for industry professionals with five to ten years of experience.

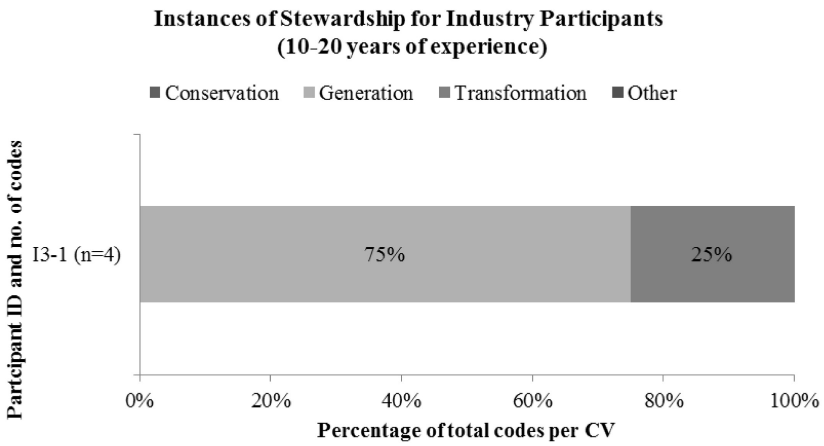


**Fig. 7.** Percentage of instances of conservation, generation, and transformation for industry professionals with ten to twenty years of experience.

displays more instances of generation, and I2-2 displays more instances of transformation (Fig. 6). The instances in generation for I2-1 mostly are publications at professional conferences. I2-2's transformation is high given her numerous service and outreach activities, including mentoring of women in engineering.

*4.3.3 Between ten to twenty years*

We only have one participant, I3-1, with 10–20 years working experiences in industry. The participant demonstrated more instances of generation than the other two dimensions (Fig. 7). Generation mostly relates to leading or to executing engineering projects, such as to developing and implementing new technology.

*4.3.4 Greater than twenty years*

There are two participants, I4-1 and I4-2, with more than 20 years of industry experience. They both demonstrate more instances of generation than the other two dimensions (Fig. 8). It should be noted that I4-1 holds a title of Director of Research and Development, and I4-2 holds a title of Director of Process Engineering. They both seem to be heavily involved in research and development, and their job experiences related to leading and to implementing engineering projects or to writing technical publications.

*4.4 Trends across engineering Ph.D. holders working in academia and then industry*

Since there are so few academia to industry partici-

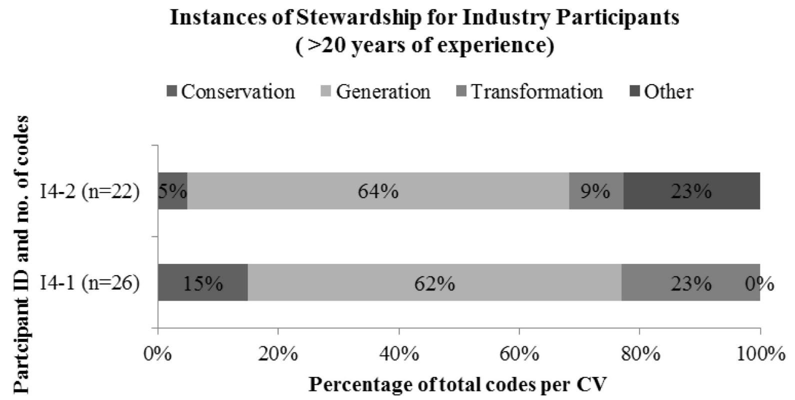


**Fig. 8.** Percentage of instances of conservation, generation, and transformation for industry professionals with greater than twenty years of experience.

pants, one table is presented for all participants within this occupational sector (Fig. 9).

Although all participants in this group currently work in industry, AI2-2 spent the majority of time working in industry, while the other participants in this category spent the majority of their time working in academia. AI2-2 and AI2-1 had comparatively abbreviated CVs compared to the other participants. While AI2-2 appeared to have been more selective with what was included and provided descriptions as necessary, AI2-1 presented more of a tabular summary of positions, publications, and students supervised. As a result, AI2-1's instances of generation are likely skewed, since, instead of listing individual conference publications, he briefly listed of names of some conferences along with an indication that ">80" were included in the CV. Although the coders counted these 80 publications as generation, they had no way of knowing how many of these publications were received post Ph.D.

Patents dominated transformation for all participants with the exception of AI2-4, who listed more conference presentations and new course development activities during his time in academia.

Similar to examples given in the academia only sector, conservation appeared mostly in relation to supervision of students and to conservation of roles within their professorships (e.g., required teaching of courses and serving on university committees). A higher percentage of AI2-2's conservation instances showed up as participation as a contributing member or officer in national professional organizations and supervision of Master's thesis committees during his time in industry.

From a general review, there were few noticeable differences in this sector when compared to the industry only and academia only sectors, and instances of stewardship were displayed regardless of participants' employment in industry or academic position at various points in their careers.

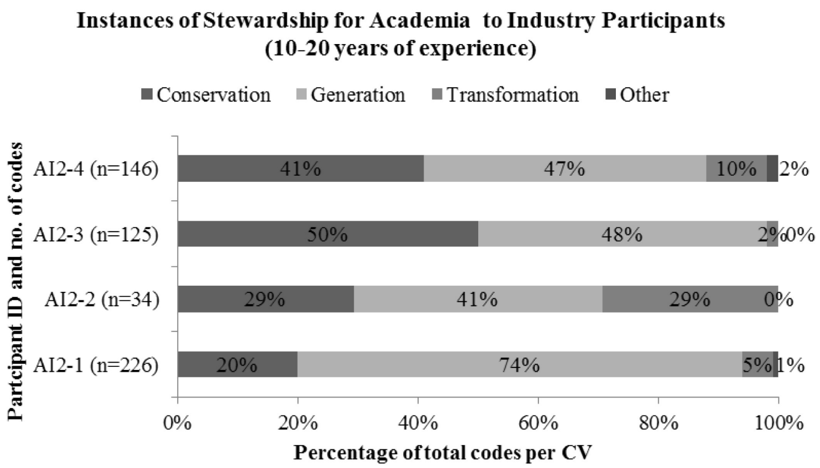


**Fig. 9.** Percentage of instances of conservation, generation, and transformation for academia to industry professionals with ten to twenty years of experience.

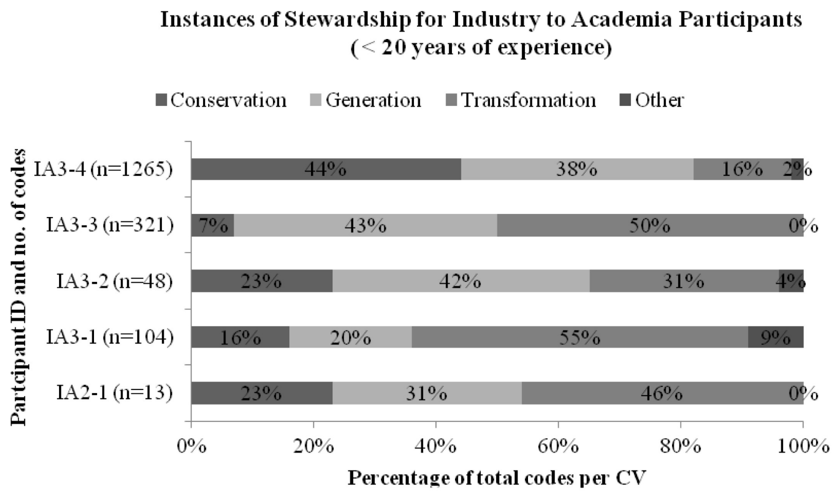


**Fig. 10.** Percentage of instances of conservation, generation, and transformation for industry to academia professionals with less than twenty years of experience.

### *4.5 Trends across engineering Ph.D. holders working in industry and then academia*

#### *4.5.1 Less than twenty years*

Figure 10 displays the instances of stewardship for all participants with less than 20 years of total experience in industry and then academia.

Additional insight about the analyses of IA3-2, IA3-3, and IA3-4 are presented below. IA3-2, whose profile represented the most balance across stewardship and "other," completed his Ph.D. as a Senior R&D Engineer and remained in industry for two years. Subsequently, IA3-2 served as a scientific advisor to industry before transitioning to academia as a chair of an engineering department. IA3-3, who demonstrates the highest instance of generation across participants, worked in a national lab upon receipt of the Ph.D. for 3 years before transitioning to Professor roles and ultimately Chair of his Engineering school. Finally, IA3-4, who reported the higher instance of conservation, completed his Ph.D. as a research engineer and served for a year as a visiting research scientist within industry before transitioning to academia. For the remaining sixteen years included in the CV, IA3-4 held a variety of positions including affiliate faculty roles and is currently a full professor within his engineering discipline. IA3-4's CV was one of the most detailed (53 pages) and demonstrated a diverse range of stewardship experiences throughout his career.

#### *4.5.2 More than twenty years*

Figure 11 displays the instances of stewardship for the two participants with more than 20 years of total experience in industry and then academia.

IA4-1 is a distinguished professor, and 70% of his

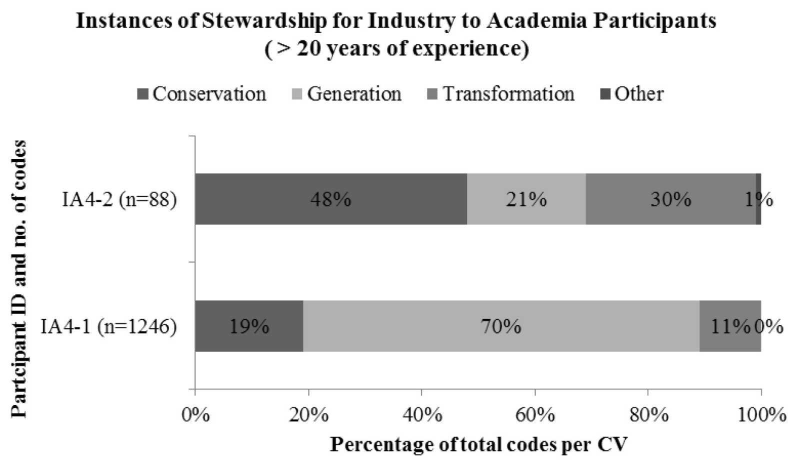


**Fig. 11.** Percentage of instances of conservation, generation, and transformation for industry to academia professionals with greater than twenty years of experience.

instances relate to generation. He started his career in industry and held a position of District Manager before entering academia, where he has worked for twenty years and began as a Full Professor. He has served as principal investigator for 77 grants from many different funding sources, has published over 250 peer-reviewed journal articles and 400 conference papers, has obtained 20 patents, and has graduated numerous Master's and doctoral students. The number of coded instances within different tenets adds up to 1246, the highest of any participant in this study. In addition to these activities, generation was also demonstrated via his technical experiences and accomplishments related to technological innovation and implementation. Conservation relates mostly to his involvement in professional disciplinary organizations, and transformation is represented in activities such as conducting seminars or workshops or lecture invitations.

In contrast, IA4-2 spent most of his career in industry. After his retirement, he founded a consulting company. He currently holds an appointment as a senior lecturer in a university. Of all stewardship tenets, he demonstrates the highest instances of conservation, which come from his experiences serving in professional organizations and on university boards or national councils to enhance aspects of his field in areas such as assessment and evaluation and sustainability. His high instances of transformation come from his speaking engagements and service in a variety of panels and workshops.

## 5. Discussion

Although several studies focus on the skills needed for engineering graduates pursuing both academic and industrial careers, these studies have not been mapped to the tenets of Golde and Walker's [5] stewardship framework. Included within this discussion are details about the operationalization of generation, conservation, and transformation among participants as informed from their CVs. Related to stewardship, industry participants reported higher generation and conservation than academia only participants; academia to industry participants reported higher instances of generation followed by conservation; industry to academia participants, on average, reported higher generation; and a new category, "other," was the lowest instance across all groups.

### *5.1 Generation*

Golde and Walker [5] described generation as "the ability to conduct research and scholarship that make a unique contribution and meet the standards of credible work (p.10)." This definition of generation within the context of engineering as presented within the CVs was operationalized in several ways. Generation was demonstrated via descriptions of academic and industry job titles (professor, researcher, director, etc.); awards and honors that demonstrate advancement in the field; scientific accomplishments as an individual or in research group, research initiation, and promise; publications in journals, books, conference proceedings, or technical briefs; grants in which participants served as a principal investigator (PI) or as a Co-PI, and authorship as first or contributing author.

Some differences were found in how generation was operationalized within academia and industry. Within academia, publishing often occurred at national and international disciplinary engineering conferences with some generation involving publications in non-engineering areas related to science, technology, engineering, and mathematics (STEM) education, pedagogical research, graduate and undergraduate course development, engineering outreach, and increased representations of women and minorities in engineering. Publications in industry, on the other hand, often resulted in internal company publications and journals. Major generation tasks within industry also related to leading process development and technology; analyzing technical analysis; and engaging in disciplinary engineering tasks.

It seems that most of our participants in industry have quite higher representations of generation compared to the other two tenets in the stewardship framework. This might relate to the demand in industry to be innovative and to adapt to technology and research development [19]. It is critical to engineering companies to develop new technology and new products within the constraints of time and cost. This observation suggests the importance for professionals who are entering the industrial environment to be innovative and adaptive in developing new technology, products, or services.

### *5.2 Conservation*

Conservation involves the maintenance of "the continuity, stability, and vitality of the field" [5, p. 11]. Tasks of conservation across CVs are noted by descriptions of academic and industry job titles (the teaching component of an academic title, information management, etc.); serving as a referee of journal and conference papers; and obtaining awards and honors that suggest participants' critical impact in a field, their scientific accomplishments individually or within a research group, or mentorship. Also included is participation in professional disciplinary organizations as a panel lead or reviewer for research projects or as a contributing member (i.e., officer, non-officer, or advisor) within national, regional, or local organizations. Other aspects of conservation include the supervision of students (includes high school, undergraduate, and graduate students as well as post docs and research associates) and thesis committees along with training certifications.

We found that participants with work experiences in academia demonstrated higher instances of conservation than participants with work experiences only in industry. This might be a result of institutions' explicit expectations that faculty teach, advise, and mentor the next generation of scholars or may occur because of increased opportunities for faculty to engage in conservation. Conservation within industry, however, is not as evident, and as such, might need to be operationalized in greater detail within the context of Golde and Walker's [5]definition.

### *5.3 Transformation*

Golde and Walker identified transformation as "encompass[ing] teaching in the broadest sense of the word" [5, p. 11]. Given this somewhat ambiguous definition, transformation was found to represent multiple facets. Within the CVs, transformation was identified through formal and informal teaching experiences, teaching awards and honors, presentations and poster sessions, professional societies and organizations outside of the discipline, commercialization and entrepreneurship, invited talks, and patents. Although transformation was quite traditional within academic environments, commercialization and patents were more prevalent instances of transformation within industrial environments.

### *5.4 Other*

Although the majority of activities within the CVs were coded within the stewardship framework, several CV occurrences did not fit neatly into the framework. For that reason, a classification of "other" was created. Among the activities coded within this category included activities related to self-improvement, participation in research or other studies, non-disciplinary awards and honors, and non-work-related jobs. This category demonstrates the well-rounded nature of several participants who engaged in professional development workshops and community service activities and raises a concern about the possible limitation of the stewardship framework in defining scholarship among engineers who hold Ph.D.s and work in academia and industry.

## 6. Limitations

Sources of limitations for this study stem from two main areas: (1) the variance in content organization of the CVs and (2) recurring codes across multiple sections of CVs. Since participants' current CVs were collected as part of a research study on professionals with Ph.D. degrees and no set template was required for CVs, participants' CVs varied in length and content. While some participants provided detailed descriptions about the nature of their professional activities, others listed brief job titles with no descriptions. Although such details provide insight into what participants considered to be important, these variances required coders to determine the extent to which those activities fit within a stewardship framework. Another issue is that the submitted CVs may have been embellished by the participants or may have been tailored to specific jobs or to audiences that might have valued certain professional activities over others. As an example, someone submitting a CV that was submitted for promotion to a research-intensive job might have omitted items related to conservation or to transformation, since generation is perceived to be more attractive for a research position. Also, some overlap in coding may have occurred given the placement of some activities (e.g., best paper awards and publications) in multiple sections of the CV. This is especially prevalent when coding society memberships, activities, awards, and honors. Finally, all publications were considered in the coding, since it was not possible to distinguish between peer-reviewed papers and non-peer-reviewed papers.

## 7. Future work

This work lays a foundation for future work regarding stewardship among engineering Ph.D. holders working in industry and academia. First, the diverse career paths pursued by participants at various stages of their professional careers after obtaining their engineering Ph.D.s. could be coupled with the stewardship activities identified within this paper. Second, the stewardship codebook developed within this study might be used as a template in the analysis of other CVs. Such analyses might inform engineering Ph.D. holders about the alignment of their work to scholarship expectations within engineering and might provide a guidebook for doctoral engineering students who want more insight about activities that are expected of them as Ph.D. graduates. Additional analyses of stewardship may be explored across engineering disciplines, by nationality, and by gender. Third, since all participants have also been interviewed about their experiences after receiving engineering

Ph.D.s, CV data will be triangulated with qualitative findings that might provide additional insight about other instances of stewardship in which respondents are engaging.

## 8. Conclusions

This paper explores the operationalization of stewardship among thirty-six engineers with Ph.D.s working in academia and industry. Considering that the majority of the participants work in research-related careers, generation is the most frequently occurring stewardship tenet, followed by conservation and transformation. Since not all CV occurrences aligned with the stewardship framework, an additional category called "other" was created. Researchers found that stewardship differed in academic and industrial settings and that the activities of engineers working in academia most closely align with the traditional expectations of doctoral scholarship.

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