Who are EEC NSF CAREER awardees?: Educational Backgrounds, Institutional Affiliations, and Public Award Abstracts

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***Abstract*—This research category full paper explores National Science Foundation (NSF) Faculty Early Career Development (CAREER) Program awardees from the Division of Engineering Education and Centers. The NSF CAREER Award distinguishes researchers as promising future leaders who are advancing the frontier of engineering education research (EER). Additionally, the multidisciplinary rise of EER has resulted in a diverse community of researchers from many backgrounds and academic departments. Given the recognition associated with the CAREER award, it is crucial that all early career faculty members possess the knowledge and support to create high quality CAREER applications. In this study, we investigated the educational backgrounds, institutional affiliation, and public abstracts of CAREER awardees to document prevailing patterns in recognition through CAREER awards. This knowledge informs future work to provide additional support for early career faculty planning on applying to the program.**

Keywords—NSF CAREER, early career faculty development, engineering education departments, lone wolves

I. Introduction

Grant funding is a crucial metric for the tenure and promotion of faculty members [1]. With such attributed importance, it is vital to recognize key supports and barriers that may occur during the grant application process, especially for faculty who may be the only engineering education faculty at their institution [2]. In this article, we investigated a prominent, prestigious source of funding–the National Science Foundation (NSF) Faculty Early Career Development (CAREER) Program–to begin to explore the experiences of those who have received the grant in engineering education. These findings can inform future efforts to build infrastructure that connects engineering education research community members and supports all faculty who are developing as engineering education researchers.

Engineering Education Research (EER) has developed into a field of expertise and a career pathway over the past three decades [3]—[5]. In response to numerous reports in the 1990s and early 2000s [6]—[9], multiple EER graduate programs were established in the mid-2000s and a growing number continue to emerge to educate and train the next generation of EER faculty and policy makers. EER is characterized as a field with departments and degree programs, high-profile publication outlets, research funding streams, professional societies, and annual conferences [10], [11]. As EER taken on this identity, it has also developed norms and rhetoric to articulate community values. Researchers without connections to EER departments or centers may benefit from social infrastructure that helps connect them to these larger community conversations. To this end, we consider individuals who received NSF CAREER Awards to understand the distribution of backgrounds, institutional affiliations, and research topics within publicly available information.

The NSF CAREER Program is a five-year and at least $500,000 grant awarded to tenure-track faculty members, with the goal that researchers use the funds to establish their research agenda that will define the rest of their careers [12]. The grant recognizes pre-tenured faculty with high potential for success, distinguishing them as promising future leaders who are advancing their respective fields. Due to the peer-reviewed nature of NSF proposals, CAREER awards not only distinguish individuals, but also communicate the values and zeitgeist of the research community.

II. NSF CAREER Award

In this section, we describe the history and application process for the program, leading into to describing the purpose and research questions guiding our analysis. The NSF CAREER Program began in 1995, with the first grant within the Division of Engineering Educations and Centers (EEC) awarded in 2003. During this interlude, several CAREERS awards were topically related to engineering education, but housed in other engineering divisions. To create a more precise and bounded analysis, this study addresses EEC-funded CAREER awards, although we recognize the contributions to the community from other NSF directorates. To date, 3,750 CAREER awards have been distributed within the Directorate for Engineering; a subset of 46 awards are housed within EEC. The number of CAREER awards is variable and subject to the Program Director's portfolio goals for their term [13].

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Eligible applicants are tenure-track assistant faculty members at any institution of higher education, which includes both four-year and two-year institutions [12]. Applications to the NSF CAREER Program take the form of a proposal with both research and education activities that articulate how this endeavor will form a foundation for the applicant's academic career. Applicants may submit one proposal per competition year and are limited to three total proposals.

An additional aspect of the NSF CAREER Program is that especially high-quality applications are nominated for Presidential Early Career Award for Scientists and Engineers (PECASE) Awards. This additional distinction also solicits applications from multiple federal funding agencies and grants awardees a visit to the White House. In 2016, 105 PECASE grants were awarded; 21 of those grants were nominated through the NSF [14].

Given the recognition associated with the CAREER award, it is crucial that all early career faculty members possess the knowledge and support to create high quality CAREER applications. To this end, we examine successful applicants' backgrounds and experiences, as well as the topics explored within successful proposals. This investigation reveals not only opportunities to support potential applicants, but also how award patterns may reflect broader trends within the EER community. Our research questions were:

1. What is the distribution of educational backgrounds of successful NSF CAREER applicants?

2. What is the distribution of departmental and institutional affiliations of successful NSF CAREER applicants?

3. What are broad patterns and characteristics of the topics described within successful NSF CAREER proposal abstracts?

III. Literature Review

Although CAREER grants are awarded in all disciplines within the NSF's purview, academic conversations about the program have primarily been housed in EER spaces. For one, the rise of EER has resulted in a diverse community of researchers from many backgrounds and academic departments [3]—[5], meaning that CAREER application guidelines are not a one-size-fits-all formula. In both EER and the broader research community, most publications on NSF CAREER Awards take the form of conference papers and focus on recommendations for applying to the program. There have been limited systematic explorations of the effects of an NSF CAREER Award. One ten-year retrospective study was built into a CAREER workshop and demonstrated that CAREER awardees were more likely to receive tenure, compared to non-awardees [15]. To date, there have been limited explorations of the backgrounds, experiences, and research interests of successful applicants.

This study fits within broader conversations around exploring and supporting the diversity of individuals within the EER community. Despite the establishment of EER as a field of inquiry, the social infrastructure available to engineering education researchers is not yet robust enough to consistently support the development of early career faculty across different types of appointments (within EER departments, as faculty in traditional engineering disciplines, or as a part of centers, etc.; [2], [16]). There have been a number of workshops and similar programs over the past decade with a focus on "rigorous" education research to bring peripheral members of engineering education into a more central position [17], [18]. These efforts have mostly focused on inquiry methods from education and social science, rather than bringing new researchers into the EER community. To date, there are no formal programs (i.e., dedicated infrastructure) to bring central members into core positions within the community. More informal structures like the PEER Collaborative work, a national peer mentoring network for early career faculty focused on engineering education research [19], has proved valuable for providing an emergent structure of mentoring, connecting, career planning, and confidence building in early career researchers. This informal infrastructure has continued to grow by word-of-mouth each year to include a greater number of early career faculty. However, this unconference is only held once a year after the ASEE Annual Conference and Exposition. This limited engagement privileges already well-connected early career faculty who know about the event and have the funding to stay in the conference city for an additional day. Within this broader topic of remaining open to multiple pathways into EER, examining the microcosm of the NSF CAREER award is a particularly generative lens to understand both researcher heterogeneity, as well as ways in which the awards may communicate (explicitly or implicitly) the values of the EER community.

IV. Methods

In this study, we were interested in exploring the distributions of educational backgrounds; departmental and institutional affiliations; and research topics for successful NSF CAREER awardees. The analyses used in this study are entirely descriptive and focused on the creation of images to visualize the "landscape" of NSF CAREER awards, in terms of the distribution of select attributes over time. This exploration was generated through publicly available information.

A. NSF CAREER Awardees

A list of CAREER awardees was generated through the NSF awards database. The search contained the CAREER reference code (1045) within the Division of Engineering Education and Centers. The search described in this manuscript was conducted on March 5, 2019 and resulted in a list of 53 awards. In this database, awards are listed twice when a researcher transfers institutions while holding the grant. Correcting for duplicates led to a final number of 46 awardees at the time of creating this manuscript.

B. Educational Backgrounds

As a first step to understand the landscape of the NSF CAREER award in engineering education, we cataloged publicly available information about the educational backgrounds NSF CAREER awardees. We operationalized "educational background" as the terminal degrees (i.e., PhD)

achieved by the awardees. This information came from institutional biography pages and published curriculum vitae. We recognize that other educational backgrounds may be salient to awardees; this information was less publicly available and as such was not included in the analysis.

After collecting the title of the terminal degree and the department from with the degree was granted, we developed categories to inductively group awardees. These categories reflected the focus of the department from which the degree was granted, since this focus likely shaped the educational experiences of the awardees. Categories were iteratively developed through a constant comparison approach. Categories were developed by the first author and checked by the coauthors to ensure categories reflected not only the data, but also recognizable divisions within the EER community.

C. Institutional Affiliations

Next, to study the career pathways of CAREER awardees, we examined institution affiliations at the time the award was granted. These data were generated from the NSF awards database and departmental websites. We distinguished between institutions with dedicated engineering education departments (i.e., Clemson University, Purdue University, Utah State University, and Virginia Tech historically and Arizona State University, University of Michigan, and Ohio State University more recently) from institutions without formal departmental structures uniting engineering education researchers. This distinction was made to distinguish programs with a built-in EER community through departmental structure, although we recognize that internal organizations and interest groups exist to connect researchers at institutions without dedicated education departments. These additional sources of support are further addressed in the discussion section of this manuscript. Additionally, it is possible for awardees to change institutions after receiving the award. In these cases, we investigated the institution at the time of the award to better account for community supports and resources during the application development.

D. Public Abstracts

Finally, we engaged in a content analysis of the CAREER proposal abstracts, which are available on the NSF awards database. Content analysis is an appropriate lens for this exploration because the data were not interpretively generated but instead come from publicly available proposal abstracts in the NSF database [20]. Content analysis primarily focuses on word choice, word distribution and similar broad trends in the data [21].

We documented the common characteristics of the award abstracts, which included the population, methods, and patterned changes in structure over time. This analysis is a surface-level overview of patterns and trends within public abstracts and may not be representative of the proposals as a whole. As with the descriptive quantitative explorations described above, the goal of this analysis was to examine broad commonalities and differences as a first step to uncovering means to support potential and existing CAREER awardees.

V. Results

A. Number of awardees

A total of 46 awardees were identified in this search. Complications arose when compiling awardee names because the named principle investigator (PI) in the award database did not always refer to the individual who originally was awarded the grant. For researchers who moved to non-tenure-track positions (e.g., NSF Program Officer), the PI title was transferred to the researchers' department heads. After correcting for these anomalies, in Figure 1, we represent the 46 awardees distributed over time. This image provides context

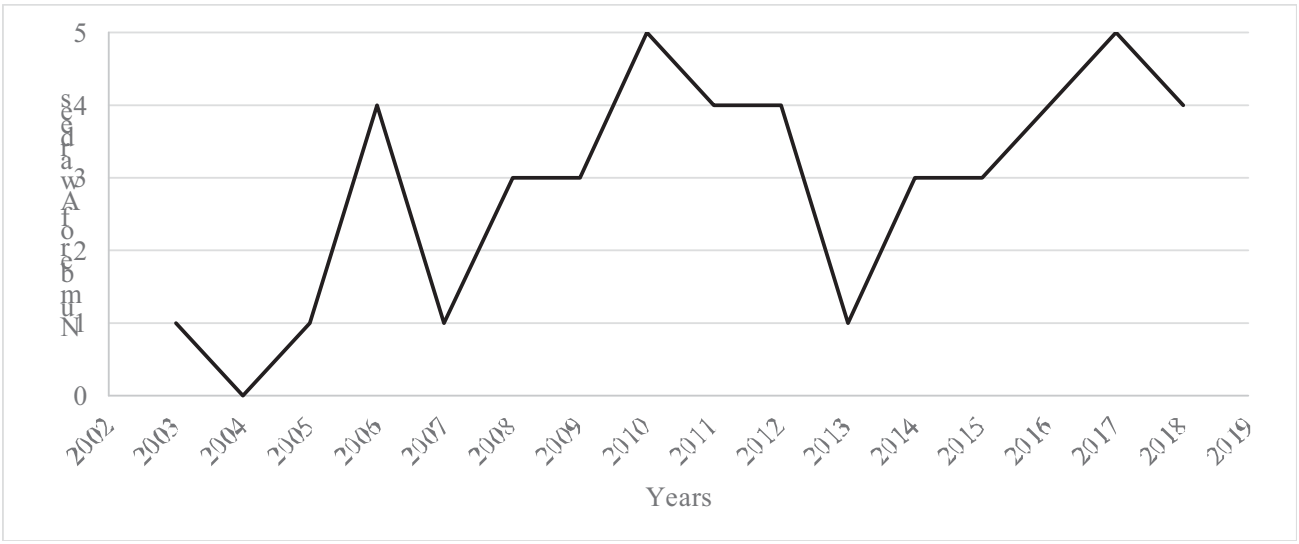

Figure 1. Trends in number of awards given from 2003-2018.

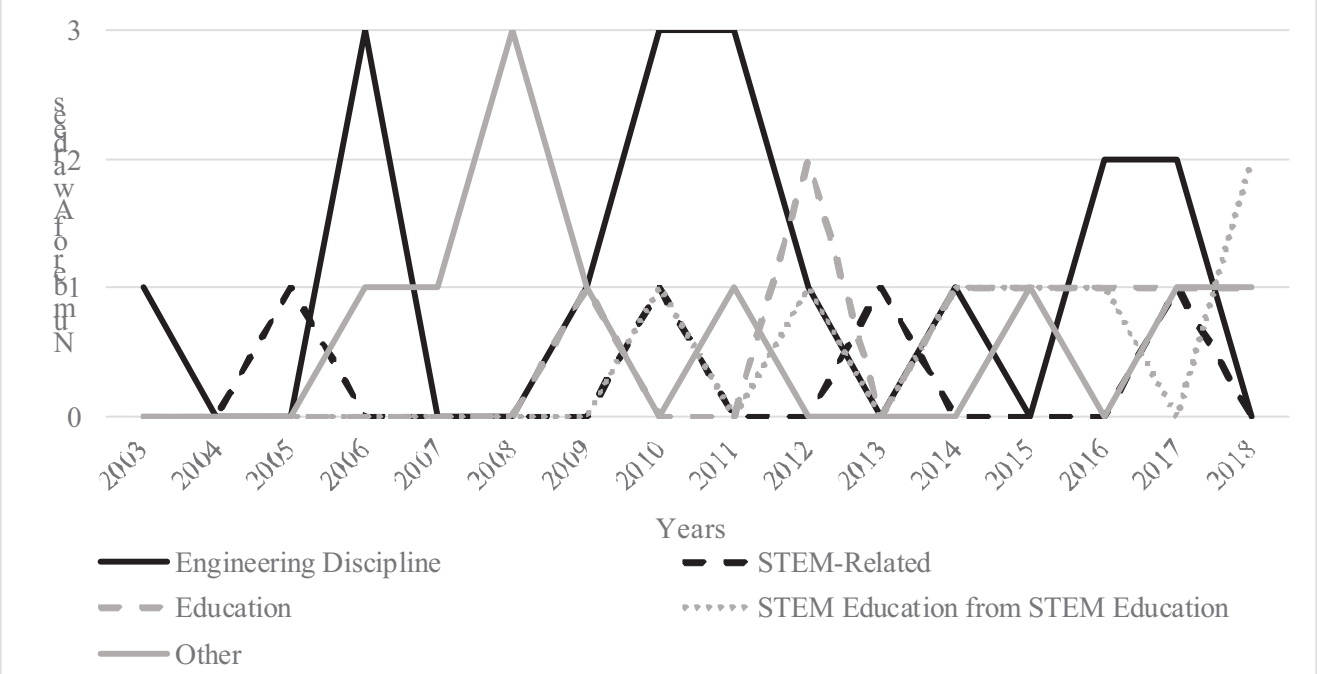

Figure 2. Terminal degrees of NSF CAREER awardees each year

for subsequent findings. Findings are not normalized by cohort amount to maintain representation of the variation in the size of each cohort.

B. Educational Backgrounds

We wanted to find a way to organize and categorize the educational backgrounds of the awardees, although we recognize that these backgrounds may not completely reflect the identities and perceptions of the awardees. As previously described, we focused these categories on the department in which the degree was held. Additionally, in this section we use the term "STEM" rather than "engineering," to account for nuances within degree titles.

There was a total of 30 unique terminal degrees. We collapsed these degree titles into one of five categories. These categories–Engineering Discipline, STEM-Related, Education, STEM Education from STEM Education-Specific Departments, and Other–reflect the interdisciplinary nature of the EER community. Below, we describe each category in detail. "Engineering Discipline" referred to degrees that came from historically recognized engineering disciplines (e.g., mechanical engineering, chemical engineering). "STEM-Related" was used to describe terminal degrees topically related to STEM, but outside the historical engineering disciplines (e.g., socio-technical studies, engineering and public policy). "Education" referred to degrees housed within education departments, which included several terminal degrees with STEM education concentrations. The category, "STEM Education from STEM Education-Specific Departments," was used to describe the relatively recent phenomenon of terminal degrees in STEM education housed in departments specifically related to STEM education. Finally, we used the "Other" category to describe terminal degrees that are not topically related to STEM such as English or Leadership and Policy Studies, although awardees' dissertation research may have been related to STEM topics.

Using these categories, we charted the distribution of NSF CAREER awards over time, as shown in Figure 2. We found that the prominence of Engineering Discipline degrees transitioned to a more even representation across all five categories. Prior to 2013, Engineering Discipline terminal degrees were held by 46% of awardees; after, these degrees were held by 25% of awardees. The relatively recent development of STEM Education-specific departments was also reflected in the data; five awardees since 2014 received terminal degrees in engineering or science education from such departments.

C. Institutional Affiliations

We examined the institutional affiliations that awardees had when they received the CAREER award. As a reminder, we distinguished between institutions with engineering education departments (i.e., Clemson University, Purdue University, Utah State University, and Virginia Tech historically and Arizona State University, University of Michigan, and Ohio State University more recently) from institutions without such departments. Figure 3 shows the distribution of these two categories over time. Over the entire lifetime of the NSF CAREER Program in EEC, we found an even split between the institutions with engineering education departments and those without; 24 researchers were from one of the four original engineering education departments and 22 were from "Other" institutions. There was one anomaly year, 2015, in which all three of the awards came from Purdue University. However, more recent award indicates that a majority of awards come from institutions without formal engineering education

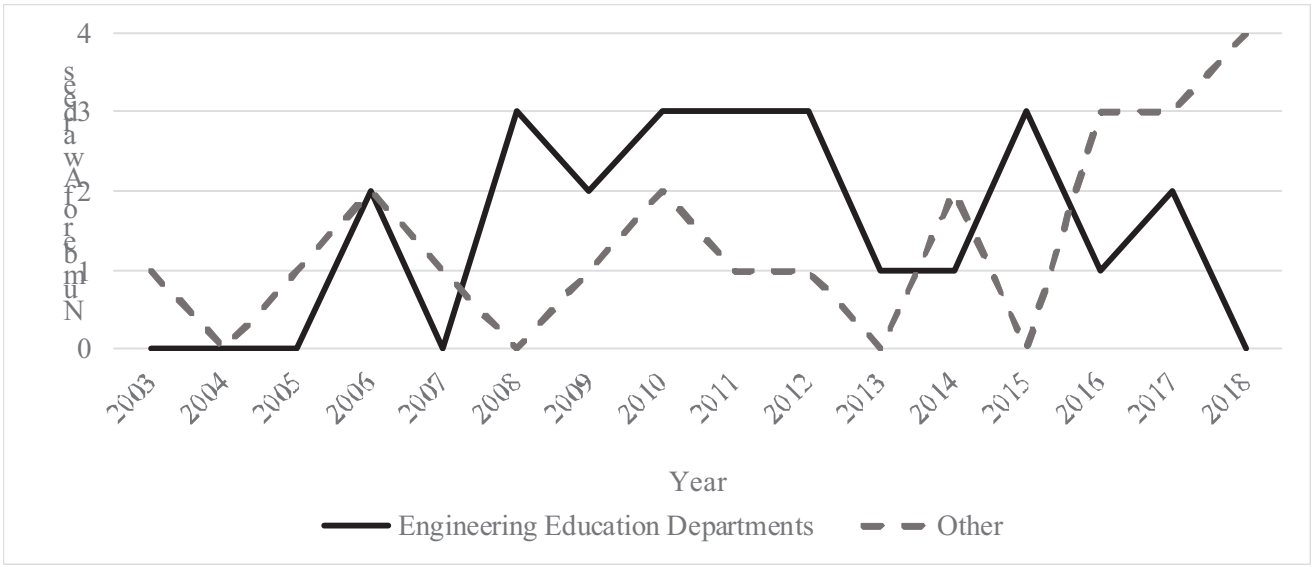

Figure 3. Institutions of NSF CAREER awards each year.

departments. In the past three years, individuals at these "Other" institutions made up ten of the thirteen awards.

D. Public Abstracts

Using content analysis, we examined the public research abstracts of the 46 awards. Below, we describe patterns in the population of interest, the method of inquiry, and apparent changes over time. These patterns highlight the ways in which the engineering education research field is simultaneously evolving and tied to its historical roots. While broad trends can be identified, we also stress the individual nature of proposals that is inherent to a grant strongly associated with innovation. As such, the identified patterns should be interpreted as descriptive rather than prescriptive.

1) Population

The majority (27 of 46) of proposals included studying (at least in part) the experiences and beliefs of undergraduate engineering students. Within this broad population, some abstracts described intentions to only study select groups or types of students (e.g., underrepresented students). Other abstracts describe data collection from undergraduate engineering students, broadly, with plans to disaggregate data by gender, race/ethnicity, etc. Beyond those studying undergraduate engineering students, the 19 other abstracts described a wealth of foci, including K-12 students, engineering graduate students, professional engineers, and engineering disciplines as a whole. Thus, while the majority of abstracts addressed undergraduate engineering contexts, a sizable proportion of proposals (41%) investigated other populations within the purview of engineering education.

2) Methodology

Many abstracts (20 of 46) described a mixed or multi methods approach to understand the research topic, either by explicitly identifying the research as mixed methods or by describing the use of both quantitative and qualitative data. A smaller proportion of abstracts (9 of 46) described studies that drew upon either solely qualitative or quantitative data. Finally, the remaining 17 other abstracts did not contain an explicit discussion of the types of data that the PI intended to use in the project. These abstract often included terms describing the research process that were not necessarily tied to one type of data strand (e.g., "identify" or "evaluate").

3) Changes over time

We identified two trends that were tied to changes over time, which may speak to the evolution both of the EER community and of the requirements of NSF for public abstracts. First, the length of the listed abstracts changed dramatically. From 2003-2014, the average abstract length was 204 words. From 2014 to 2018, the average word count was 404 words. This change is important to note to contextualize the content of the abstracts; the abbreviated nature of the abstracts may belie the actual content of the proposals. Additionally, from 2011 to 2015, just over half (7 of 12) of abstracts explicitly aligned the study with the strategic goals of the NSF. Indeed, these abstracts included the phrase "This project overlaps with NSF's strategic goals of…," which suggests that the phrase was a verbatim guideline from NSF. While potentially minor trends, these changes may represent the evolving standards and practices of engineering education research.

VI. Discussion

This analysis explored the diverse and evolving community of leading engineering education researchers, as characterized by NSF CAREER awardees from the Division of Engineering Education and Centers (EEC). Below, we connect our findings from publicly available information to larger conversations within the engineering education community. These connections serve to ground discussions in evidence as well as focus the conversations on ways to support members of the EER community.

A. Educational backgrounds

To answer the first research question, we examined the educational backgrounds (in terms of PhD degree) of successful NSF CAREER awardees. While many early awardees held terminal degrees in an engineering discipline or a field completely outside of STEM, recent award cohorts have featured an array of educational backgrounds. Additionally, we noted the increased representation of awardees with terminal degrees from STEM-education specific programs (as opposed to STEM education housed within an education program). The creation of these programs, beginning in 2004, has equipped researchers with skills and knowledge specifically designed to support successful engineering education research. However, it is important that the community continue to recognize alternative pathways into the EER community, as well as the pathways that STEM education graduates may take after graduation. Part of this recognition includes having conversations about the potential homogenization of research rhetoric, as an increasing proportion of the EER community are formally trained with PhDs in engineering education.

Historically, many researchers came to EER as individuals trained in other disciplines, but with an interest in improving teaching and learning [22]. This approach created an interdisciplinary space where many could learn the norms, practices, and language of EER as they became scholars. This history combined with the emergence of EER as a discipline with academic recognition; specific knowledge, frameworks, methodologies, and ways of conducting research; and particular emphasis and goals [23], creates a tension for building capacity to continue to develop EER and also include engineering education researchers who have not completed PhDs in an engineering education program. If EER is to continue to develop and emerge as a strong and robust discipline with high quality engineering education research, support mechanisms must be developed to both recognize outstanding EER scholars and develop the next generation of researchers in the field. The risk of becoming siloed as a discipline is exclusion of new researchers, which can hamper innovative and transformative research.

B. Institutional affiliations

To answer the second research question, we investigated the appointment of awardees at the time that the award was announced. We characterized the appointment as whether or not it was within a department devoted to EER—essentially distinguishing whether or not the awardees held a position at the four oldest PhD programs at Clemson, Purdue, Utah State, or Virginia Tech. The trend of awards at engineering education programs may change as new PhD granting programs have been created. This interpretation allowed us to indirectly capture the extent to which awardees may receive institutional support such as easy connection to mentors, a business office familiar with educational research, and promotion and tenure committees familiar with the practices of EER. However, this interpretation does not capture other forms of support that may exist, such as engineering education centers (e.g., VaNTH) or inter-institutional mentorship. Broadly, these findings are a first step to understanding potential supports or barriers that awardees may face.

Cognizant of the general and exploratory nature of our analysis, our findings demonstrate that almost half of CAREER awardees may not have had access to institutionalized forms of support. Additionally, while the period of 2008-2015 had a majority of awardees with appointments in engineering education departments, this pattern likely reflects the influx of early career faculty appointed by such nascent departments. With the recent influx of awardees with appointments outside of engineering education, it is crucial that the EER community remain aware that researchers without institutional support may need additional resources and connections to facilitate both their application to the NSF CAREER Program, as well as their success in bringing accomplishing the proposed work.

Faculty who are isolated as “lone wolves” are of particular concern as EER continues to develop as a field. We define “lone wolves,” consistent with prior work by Riley, Karlin, and coauthors [2], as faculty conducting engineering education research and working for change in relative isolation at an institution [24]. These faculty are loosely or even unconnected to an existing network of EER centers and departments or may be at institutions with these structures and nonetheless be unconnected. As EER matures as a field of inquiry, it is crucial to develop social infrastructure to support early career faculty across different types of appointments (especially those as faculty in traditional engineering disciplines or outside of EER departments and centers; [2], [16]). Infrastructure is an essential part of developing and sustaining a field [11]. By understanding the current patterns of recognition in the EER community given to early career faculty, as indicated by the NSF CAREER award as one specific example, we can better understand what types of infrastructure may be needed to support networks and communities of loosely connected faculty or “lone wolves” in EER. Our initial results indicate that the NSF CAREER Program in EEC comprises both “lone wolf” researchers as well as those with institutional connections and support. Given the complex, innovative, and independent nature of CAREER awards, it may be particularly generative to target this population of awardees to understand the perceived supports and barriers they experienced in developing and accomplishing their proposals.

C. Research topics

Finally, to answer the third research question, we analyzed the content of the proposal abstracts listed on the NSF database. While describing our findings, we want to note that absence of evidence is not evidence of absence, especially when a five-year proposal is summarized into around 200 words. Additionally, these abstracts are not necessarily included in the original proposal but are instead crafted immediately upon notification of the award, while awardees

are also working with business offices and institutional review boards. Within these interpretative constraints, we found several interesting patterns relating to the structure and content of the award abstracts.

The populations identified as being of interest within the public award abstracts reflect the history of engineering education research, which developed out of undergraduate educators taking interest in their instructional efficacy [22]. After 16 years of awards, the CAREER Program represents the entire ecosystem of engineering [25], from preschool to professional practice. This finding reflects both the history and the growth of EER as a field of inquiry.

The high representation of mixed methods approaches within the study also reflect methodological conversations within EER. In a longer grant proposal of five years, many CAREER awards noted the strengths of using multiple streams of data to ask complex and innovative questions. However, this trend also brings forward an important point that there needs to be space within the methods proposed and used for sole qualitative or quantitative studies in EER. We note that while many abstracts did not identify the specific types of data, this phenomenon may be a result of a constrained word limit, which encouraged PIs communicate the goals of the research design, rather than the specific processes that would achieve those goals.

Lastly, the changes in length and the explicit connection to NSF strategic goals reflect the influence of the NSF over the form and content of the ways in which studies are communicated to the public. The current public abstract form, with the first paragraph a nontechnical description for a general audience and the second paragraph a technical description, provides more description that the shorter forms of a public abstract from the earliest CAREER awards. This change in NSF reporting requirements provided more space to describe the innovative research topics associated with the NSF CAREER award. The change in length and complexity of public abstracts over time may also indicate a maturation of the field as well. These results may be one indication of how the field is changing over time and is especially critical when considering bringing new members "into the fold" of a rapidly evolving community.

Further explorations not only of the public abstracts, but also the full body of proposals, both funded and unfunded may provide better insight into the relationship between individuals and the EER community at large. These insights may include potential sources of "hidden curriculum" [26] in the writing of CAREER proposals that may privilege community members with built-in support networks through educational backgrounds or departmental structures. These explorations would support a larger agenda of providing resources such as mentoring to broaden participation within engineering education research.

VII. Limitations and Future Work

In addition to the limitations to interpretations discussed earlier (the high-level analysis, the inductive categorizations, and the condensed nature of public abstracts), we also acknowledge the difficulty in discussing trends within a relatively small total sample that is further divided into annual cohorts. The small sample and the innovative nature of the CAREER award results in high amounts of variability, both over time and between awardees, and limits our ability to make broad, transferrable claims.

Future work extends this study by speaking with CAREER awardees to develop evidence-based insights that will drive the creation of an online community to support and mentor potential CAREER applicants. The infrastructure of the online community has transferability outside the context of the CAREER award to also provide support to researchers of all backgrounds who would like to engage in the EER community.

VIII. Conclusions

In this study, we investigated the educational backgrounds, institutional affiliations, and public abstracts of 46 NSF CAREER Awards funding through the Division of Engineering Education and Centers. We identified the diversity of awardees and the demonstrated the impact of founding dedicated engineering education departments. Through a content analysis of the abstracts, we identified trends that reflected the history and values of the engineering educational research community. These findings have implications for the development of dedicated infrastructure designed to support not only potential applicants to the NSF CAREER Program, but also individuals interested in participating in the engineering education research community.

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