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The Pioneers' Stories As A Tool For Introducing Graduate Students To The Engineering Education Research Community

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ABSTRACT

This study, framed with a socialization lens, discusses the impact of using stories about early contributors in engineering education (via results of the Engineering Education Pioneers Project) as a mechanism to help socialize the first cohort of graduate students in a new engineering education Ph.D. program. Two instructors designed a new course requiring five students to read selected pioneers' stories weekly. Students subsequently wrote weekly reflections about the stories and submitted a final synthesis of their reflections at the end of the semester. Findings presented using a student-led autoethnographic approach include highlights and themes describing the overall impact of the pioneers' stories to facilitate an understanding of the field and develop an identity as an engineering education researcher. Findings also include the instructors' observations of the stories' impact on students' professional formation. Implications for various stakeholders in the engineering education ecosystem are discussed.

Key words: Graduate PhD students, Career paths, Developmental theory

INTRODUCTION

The field of engineering education has significantly grown over the last century (Froyd, Wankat, & Smith, 2012; Jesiek, Newswander, & Borrego, 2009). Based on Fensham's (2004) framework for describing indicators of a mature discipline, the development of entities like professional societies, scholarly research outlets, organizational units within academic institutions, and external support (e.g., National Science Foundation) dedicated to engineering education all serve as growing evidence and a foundation for this maturing field of scientific inquiry (Froyd & Lohman, 2014). Noteworthy efforts giving credence to the field's development include a recent synthesis in the *Cambridge Handbook of Engineering Education Research* (*CHEER*) (Johri & Olds, 2014) and the formation of Ph.D. programs solely focused on training and socializing the next generation of engineering education researchers. These entities collectively serve as strong indicators of a maturing discipline, community, or field (Fensham, 2004; Jesiek et al., 2009).

With growth comes the need to identify foundational knowledge and to establish pathways or entry points into the field. Many mature fields have signposts, such as theories and techniques named after some of their leading scholars (e.g., Newton's Laws or Bandura's Social Cognitive Theory), to help newcomers explore the field. Engineering education has yet to reach such a point, making it difficult for newcomers to explore established and potential pathways into engineering education research and to learn about the myriad of events and people that provide the context for such pursuits. This knowledge is essential to fully assimilate into the field and become a productive contributor.

Formal training to learn about the field of engineering education has begun to emerge at the doctoral level (Benson, Becker, Cooper, Griffin, & Smith, 2010); however, those interested in becoming part of the engineering education research field may or may not have the opportunity to pursue such training. This is unlike other disciplines in which foundational knowledge can be conveyed at the undergraduate and master's levels of higher education. Alternative approaches in the absence of formal training, like attempting to individually digest the contents of a resource like *CHEER*, is a high threshold for many to cross without guidance. The lack of clear and reasonable alternatives to learn about engineering education research suggests a need for other mediums that can help people learn and understand the field. We argue that the stories of established engineering education researchers and/or change makers in engineering education, i.e., pioneers, provide an accessible point for those interested in engineering education research. Personal stories provide a powerful means of conveying insights in compact, compelling, and memorable ways (Coffey & Atkinson, 1996). It is important that those operating within the field be intentional about providing newcomers with an opportunity to increase their awareness of the experiences of those that laid the foundation for the

field. Reflecting on the significance of personal stories can provide one vehicle that can help usher newcomers into the field. Such an approach allows newcomers to also situate their work with what has been done before them and potentially shape or improve the future of the field. One source of such historical information for the field of engineering education is the *Engineering Education Pioneers Project*.

The Pioneers Project was a study of the contributions, influences, challenges, and successes of 47 "pioneers," or early contributors, in engineering education. Pioneers were openly nominated and then selected based on the following criteria: number of nominations, demographics, approximate year of entry into engineering education, engineering education-related awards, and type(s) of contributions to the field. Selection attempted to balance the goals of creating a representative sample of the community and prioritizing pioneers who were nearing retirement or had already retired. (Additional details about the Pioneers Project, the pioneer selection process, and the Profiles can be found here: http://bit.ly/engredupioneers.)

The Pioneers Project closely integrated two broad objectives: 1) to gain a contextualized understanding of past transformation efforts in engineering education and 2) to facilitate continuing transformation by catalyzing and studying the development of prospective change agents. These objectives aimed to provide a source of historical information with an explicit focus toward developing those new to engineering education. The project's core activities served both objectives by using graduate students as interviewers and profile authors of the pioneers' stories. This approach derived a unique set of immediate and long-term benefits, including learning about how these pioneers contributed to transformation in engineering education and how their stories can inform and support student development as future pioneers.

Two student interviewers, now faculty, leveraged their Pioneers Project experience in the development of a new course for the first cohort of students enrolled in the Engineering Education Systems and Design (EESD) Ph.D. program at Arizona State University (ASU). A major point of consideration in the creation of the program was selecting from a variety of ways these new scholars, i.e., the next generation of engineering researchers, could be brought into the field and made aware of the engineering education community. The first two authors of this paper co-designed and taught the first-year required course that explicitly addressed this point of consideration; they will be referred as the "instructors" throughout the rest of the paper. The instructors chose to integrate the pioneers' stories into this course to provide students with a systems-level understanding of the engineering education enterprise and the discipline of engineering education research. Particular emphasis was given to the continuum of events that have and continue to influence engineering education. (Additional details about the course will be provided in the Methods section.)

We use this concrete example of how the engineering education pioneers' stories can be used to answer our research questions:

1. Can the pioneers' stories be used to help socialize graduate students into and promote foundational knowledge of engineering education?
2. What is the impact of the pioneers' stories on facilitating an understanding of the field and the development of an identity as an engineering education researcher?

We explore our research questions by first framing our investigation using a theoretical perspective and supplemental literature regarding the socialization of graduate students into a new field. We then describe our approach to assessing the influence of the engineering education pioneers' stories, including autoethnographic statements made by students and a synthesis of student reflections performed by the instructors. This paper closes with a discussion of the implications of this study on emerging scholars, mentors, and other stakeholders focused on facilitating the entrance of newcomers into the field of engineering education.

Conceptual Underpinnings

This study's aim is to better understand how the use of the pioneers' stories within a core EESD course influenced the professional socialization of a new cohort of aspiring engineering education researchers. We chose to frame our analysis using a framework focusing on student transition to independence and socialization in graduate school in an effort to capture the effects of being a graduate student and becoming a new scholar within a field.

Transition to Independence

Going to graduate school to earn a Ph.D. often requires a shift in mindset from previous schooling or work experiences. Most prior experiences rely on an authority figure (e.g., instructor or boss) to guide the work. Graduate school requires a transition to independence and greater individual responsibility (Weidman, Twale, & Stein, 2001). Transition to independence for doctoral students includes three phases: admission, integration, and candidacy (Gardner, 2008). Admission is the time period that starts in the months leading up to applying for admissions to the graduate program and extends through the beginning of the coursework; it is the time in which the decision to pursue a particular institution is solidified, while meeting a variety of new people. Students learn through these experiences what it means to be a doctoral student, and they get initial impressions of being a professional in a new field. Integration is the time spent completing the coursework that leads up to taking exams (e.g., qualifying exam and preliminary exam). Candidacy is the culmination of coursework through dissertation research. Graduate students go from being consumers of knowledge to producers by making original contributions to the field. These three phases together constitute

the initial development associated with becoming a contributor to a new professional field and are highly influenced by student socialization.

Graduate Student Socialization

Socialization is a process by which newcomers internalize the norms, values, and behaviors of a society, field, or discipline (Lave & Wenger, 1991). The standard way of modeling socialization is as a linear process, whereby students are admitted, socialized, and finally graduated after the program of study is completed (O'Toole, 1996). For example, Thornton and Nardi (1975) theorize that there are four stages of socialization: anticipatory, formal, informal, and personal. The anticipatory stage is when an individual becomes aware of behavioral, attitudinal, and cognitive expectations. Students enter programs with preconceived notions that are usually modified when expectations are made clearer. The formal stage occurs once a student has been inducted into a program and has received formal instruction. Students determine their degree of fit during this stage (Clark & Corcoran, 1986). A transition then occurs from formal to informal when the novice learns about informal role expectations. These expectations are influenced and maximized by interactions students have with peers, faculty, and structures of the setting, which help students develop habits of mind and provide opportunities for integration (Bragg, 1976; Gardner, 2008). The final stage, personal, is when the student internalizes what has been learned to form a new professional identity. The limitation of the linear approach is the lack of mechanisms for feedback and of consideration to interactions among participants (Weidman, Twale, & Stein, 2001). It also does not account for the simultaneous socialization into graduate school, academic life, and the discipline being studied (Austin, 2002; Baird, 1990; Golde, 2000).

Alternative non-linear approaches to socialization embed components of evaluation and reflection, so that what is being done can be assessed and improved (O'Toole, 1996). A collaborative model accounts for interactions between personal, professional, and academic elements (Twale & Kochan, 1999). Interactive frameworks expand these interactions to include stages of socialization between the university, prospective students, novice professional practitioners, professional communities, and personal communities (Weidman et al., 2001). The model illustrates the dynamic nature of socialization and the complexity associated with identification and commitment to professional role development. This study assumes the non-linear approach to socialization because one of the implicit goals of the learning experience is to introduce the EESD students to the broader research community, while simultaneously facilitating the development of their identity as new scholars in the field of engineering education research.

There are core elements to facilitating the socialization process, regardless of how socialization is modeled. Weidman et al. (2001) specify three interrelated mechanisms: 1) knowledge acquisition,

2) investment, and 3) involvement. As part of knowledge acquisition, novices learn sufficient cognitive knowledge, skills, and an awareness of the normative expectations associated with the professional role they are pursuing. It is during this time that novices' knowledge of the area shifts from general to complex and specialized. This is also the mechanism by which the novice makes an assessment of his or her fitness to perform the demands of the profession, becomes aware of others' confidence in their ability to successfully practice the professional role, and begins to "cloak themselves in a [new] professional identity" until their old and new identity are merged and compatible, rather than "dissonant and competing" (Weidman et al., 2001, p. 29). Investment is the act of committing something of value (e.g., time, alternative career paths, reputation, etc.) to participate or prepare to participate in the profession. This may come in the form of actions like submitting applications for admissions to graduate school, taking courses that provide specialized knowledge, and accepting the sponsorship to pursue a new direction. Involvement is participation in the preparation for a professional role or engaging in some aspect of the professional role itself. It is through involvement that novices garner insights into professional ideology, motives, and attitudes, which ultimately leads to the development of a professional self-image (Weidman et al., 2001). These core elements provide useful understanding for how graduate students are socialized into a profession in terms of: 1) stages associated with socialization as a developmental process, and 2) mechanisms that facilitate socialization.

Socialization is particularly important for graduate students enrolled in interdisciplinary doctoral programs. Boden, Borrego, and Newswander (2011) note the impact of relationships, community, and opportunities. Students forge relationships as part of their graduate programs. These relationships include internal connections with faculty and students as well as external networking. Such networking can occur through connections made by a supervisor or by attending conferences to get to know crucial professional contacts within academia and industry. These relationships fuel the building of a community in addition to the one that has been established within a program. Working within a cohort of students facilitates a default community among students, especially when working within a shared space. A shared workspace among students also facilitates a sense of community in a variety of ways, including providing a setting for formal and informal interactions. External relationships with people in a program provide greater contact with preeminent scholars from other fields; often, these are individuals that students would not have met otherwise. Such connections are one way students can become familiar with broader professional contexts, while providing opportunities to communicate their expertise to others.

Engineering education is one of many interdisciplinary fields in which the formation of graduate programs is a fairly recent development. The processes for socializing graduate engineering students has been explored in the context of interdisciplinary programs that involve working across

organizational boundaries (Boden et al., 2001), but this topic has not been explored in the context of a field that is inherently interdisciplinary. In fact, many studies on socializing graduate engineering students focus on their involvement in a degree program or conducting research activities (e.g., Crede & Borrego, 2013; Mena, Diefes-Dux, & Capabianco, 2011; Saddler & Creamer, 2009). This study differs from existing scholarship and seeks to add to this body of knowledge by exploring the impact of one approach to socializing graduate students to the field of engineering education. Insights from existing scholarship—on the typical processes and active agents of socialization experienced by graduate students—serve as a sensitizing framework for this study.

METHODS

Context

Students in the first cohort of the ASU's EESD Ph.D. program were all required to have STEM bachelor's and master's degrees before entering the program. This requirement was set to ensure graduates would have the requisite degrees to obtain their desired job upon graduation. The typical student's background entering this new program suggested the need for a course that provided an orientation to their new field of study because it is a rarity that potential doctoral students have studied engineering education research in their prior education or work experiences.

Engineering Education Systems in Context (EGR 574) is one of six required courses in ASU's EESD Ph.D. program. EGR 574 was designed and co-taught by two of the core EESD faculty (first two authors on this paper) to provide students with a broad understanding of engineering education as a field of study. This course is intended to provide students with a systems-level understanding of the engineering education enterprise and the discipline of engineering education research as a foundation upon which students can build their expertise. The resulting course learning outcomes for EGR 574 include:

a. Observe and synthesize the past, present, and future of engineering education
b. Support students' identity development as researchers and members of the engineering education community

A semester-long learning experience centered around the pioneers' stories was designed to facilitate the attainment of these learning outcomes. This experience included three parts: 1) reading the stories, 2) discussing the stories in class, and 3) writing reflections about the stories. We identified points of alignment between the topic of the day and pioneers' stories when designing the schedule. For example, students read the pioneer story of Jack Lohmann, former editor for the *Journal of Engineering Education*, in preparation for the class in which common publication venues

were introduced. A segment of the in-class discussions was driven by students' insights that emerged from reading the pioneers' stories and connections to their own experiences. The weekly reflection assignment included the following prompts:

1. What are similarities and differences between the pioneers' stories and your own experiences?
2. What is your response to the pioneers' advice for new researchers and/or reflection questions posted in the pioneers' profiles and/or thought-providing questions discussed in class?
3. How, if at all, have this week's course readings or discussions influenced your research interests?

The content of the weekly reflections was not assessed outside of ensuring that students submitted something relevant to the assigned stories. The grade for this assignment was based solely on a final synthesis submitted at the end of the course. This 2,500 to 5,000 word submission included a summary of the student's journey as an engineering education researcher, emergent themes from their reflections, and any insights or realizations that emerged as a result of participating in the overall reflection activity.

Participants and Researchers

The methodological approach used in this study intertwines the participants with the research team. The primary participants for this study are the five students (authors three through seven) who enrolled in the first offering of the EGR 574 course. Students enrolled were all asked at the conclusion of the course if they would be willing and interested to share their experiences with the pioneer stories beyond the course. All five EESD Ph.D. students who completed the course agreed to participate in this study. The students include three women and two men; and three students of Asian and Indian descent, one African American, and one Hispanic student. All five hold bachelor's (B.S.) and master's (M.S.) degrees and came to the EESD program with a variety of industry and teaching experiences. A more detailed description for each student author is presented in the Results section as well as the Author biosketches.

The two EGR 574 course instructors were the primary researchers of this study and assisted by a graduate student researcher outside of the EESD program (author eight). Each instructor holds a doctoral degree in engineering or STEM education, has identified as a member of the engineering education research community for over a decade, and has been a faculty member for five to nine years.

Two of the Engineering Education Pioneers Project researchers (authors nine and ten) were also included as authors to provide project context and to review the emergent impacts of these stories. The result is that the students, instructors, and creators of the Engineering Education Pioneer profiles were all able to provide their insights to this study.

Data Collection and Analysis

The foundation for the data used in this study is the final syntheses students wrote at the end of the course. Each student author was instructed to revisit their final synthesis and to submit a focused reflection. This focused reflection responded to two main questions:

1. What were your emergent themes from your reflection synthesis, and how did the pioneer stories contribute to these themes?
2. How did the experience of reading pioneer stories help with your introduction into the field of engineering education research?

The Results section is organized around the responses to these two questions, including an overview of the themes that emerged in the reflections. A noted limitation of the approach taken for data collection was the framing of the main questions being biased toward how the stories "contribute" or "help." More neutral questions would be recommended in the future to potentially encourage and elicit student thoughts around how the stories were not impactful.

The resulting student-focused reflections around the positive contributions of the pioneer stories provide an internal perspective of the students, while analysis of these responses by the instructors provides an external perspective. This approach entailed thematic analysis (Braun & Clarke, 2006) of student derived emergent themes by the instructors and direct statements made by the students in their own voices. The students' voices were captured through an autoethnographic approach wherein the students were given the opportunity to provide their perspectives about the experience in their own words as co-authors of this paper (Ellis & Bochner, 2000). The approach leverages the tenets of autobiography and ethnography to understand a personal, lived experience. This systematic approach provides an analysis of one's own experience rather than interpreting another's experience, which provides an alternative form of validity and reliability to the emergent findings (Ellis, Adams, & Bochner, 2011). Uses of autoethnography have seen some recent use in the engineering education literature (Sattler, Carberry, & Thomas, 2012; Sochacka, Guyotte, & Walter, 2016).

RESULTS

Our results include the collective insights of both the instructors and students because the focus of this study is on the impact of integrating the pioneers' stories as part of socializing new engineering education researchers to the field. The student perspective provides a first-person account of how the assignment impacted their introduction to the engineering education field. The instructor insights are a synthesis of emergent themes identified by the students and provide an overall glimpse into the impact the pioneers' stories had on these emerging scholars. This combination of

insights will show the outcome of the assignment as an exercise designed to meet a set of course learning objectives and will provide evidence of the personal impact of the learning experience on students' development as engineering education researchers.

Student Insights

We begin with the perspectives written directly by the students in their own voices. Each student story is preceded by a short description of who they are and what experiences they brought to their new degree program. The story is intended to share an unaltered reflection from an individual perspective. A synthesis across the reflections is provided in the Instructor Insights section.

Aisosa Ayela-Uwangue is a male African American EESD Ph.D. student originally from Nigeria. He holds a B.S and an M.S in electrical engineering. He has 10 years of industry experience as a process engineer and technical program manager. The following is his story:

> My journey into engineering education research has been shaped by the pioneer stories. My initial idea of engineering education was that it only involved teaching. As I studied and reflected upon the pioneers' profiles, I was introduced to various areas of engineering education research and impact. These areas included research on K–12 education, engineers practicing in industry, underrepresentation in the field of engineering, etc. The pioneers' profiles sparked new areas of research interests for me, resulting in the submission of two proposals for research: understanding the experiences of underrepresented minorities (URMs) in engineering careers and the individual and contextual factors that contribute to URMs' success in engineering careers. The passion and zeal of the pioneers in the face of challenges as they worked to advance engineering education research is a motivation for me to engage in scholarly work, as well as complete a Ph.D. in engineering education.

Eunsil Lee is a female Asian EESD Ph.D. student from South Korea. She holds a B.S. and M.S. in clothing and textiles. She began her Ph.D. study in textile engineering, but shifted her path toward engineering education a year later. She has two years of work experience at a research institute. The following is her story:

> I was a complete novice when I first encountered the pioneer stories. I was uncertain and nervous about my decision to shift my career path toward engineering education. Then, I read the pioneers' stories, and these stories said in chorus that I was on the right track. Their experiences showed me that even 'pioneers' had similar concerns to my own in the beginning, which made

me relieved. Their stories on how they coped with the concerns helped me learn more about the nature of the engineering education field and the attributes that engineering education researchers should be equipped with. The experience helped me to get rid of the doubt I had in my decision and encouraged me to grow my belief in what I am doing. The established belief then guided me to find my place in engineering education and bestowed courage to reach the first step into the field, which is always the hardest. Lastly, but most importantly, they were not only pioneers but good people. They made me reflect on myself as an educator and stirred up my will to attempt small changes in my life to emulate them, i.e., to be a good educator.

Mark Huerta is a male Hispanic Ph.D. student in the EESD program. He holds a B.S. and M.S. in biomedical engineering. He worked one year as a design engineer, one year teaching in higher education, and started a non-profit that provides access to clean water in the developing world. The following is his story:

The experience of reading the pioneer stories instilled a sense of confidence in my ability to advance engineering education. Coming into the program, I felt like I was taking a leap of faith by enrolling in a brand-new program in a field that is not very well-recognized even in academia. Reading the stories of the pioneers alleviated many of my concerns as they have paved the path for others, including myself, to pursue engineering education directly without having to obtain a more traditional engineering Ph.D. Reading the pioneer stories also gave me insight on the journey involved in getting to the point where you become an influential part of making positive change to education. There is a lot of wisdom to be gained from seeing how others in the field were able to get to where they are now. These stories also allowed me to discover that I shared a similar perspective and even experiences to many of the pioneers. This helped me feel a sense of belonging to the engineering education community. It also contributed to me truly believing I have the ability and passion to persevere through adversity that is sure to come on my journey. Overall, reading the pioneers stories offered a great opportunity to reflect on my journey and admire the journey and work of others in the field.

Rohini Abhyankar is a female EESD Ph.D. student of Indian descent. She holds a B.S. and M.S. in physics, an M.S. in electrical engineering, and an MBA. She has over ten years of experience both in teaching and in the semiconductor industry. The following is her story:

My introduction to the pioneers' stories played a vital role in making me feel at home within my new career path. I could instantly relate to the thought processes and career trajectories of several

pioneers. The project is a valuable resource that sheds light on the trajectories of some of the earlier changemakers, their struggles and achievements, and most importantly, their contributions to the field of engineering education. I realized through my reflections that the pioneer stories were instrumental in familiarizing me with the ecosystem of the engineering education research field. After absorbing the experiences of the pioneers, I noticed the significant fine tuning and grounding of my own thoughts and ideas about the field. The serendipitous journeys of pioneers, their organically evolved research interests, and the conclusions they drew resonated with my inferences and validated my thinking, lending me strength and courage to move forward.

Wen Huang is a male EESD Ph.D. student from China. He holds a B.S. in English and a M.S. in airplane design engineering. He has 10 years of software development experience, including eight years in the online learning software industry. The following is his story:

The pioneers' stories helped me as a new engineering education researcher to recognize that I should not only concentrate on my discipline's development, but also broaden my horizons to other relevant disciplines. The specific methods include taking part in comprehensive discipline management organizations, collaborating with instructors and researchers from other disciplines, and mastering some communication and collaboration skills. Science, technology, and engineering play an important role in our daily lives and have made great contributions to social development. We should not overlook the value engineering has on other aspects. The pioneers endeavored to create convenience for students to master various valuable skills in the workplace beyond traditional classroom-learning knowledge. The value of science, technology, and engineering is assessed by whether it can serve the society and solve workplace problems and not whether it is cutting-edge. Assessment of outcomes in practice is the best measurement of any activities' value.

Instructor Analysis

The instructors analyzed the themes that emerged from each student's reflection to identify, record, and classify the consistencies and differences in their reflections into meta-themes. The three meta-themes were related to personal attributes of the pioneers, conducting research in a new area, and the opportunity to obtain a bird's-eye view of the research landscape.

Passion, persistence, open-mindedness, and risk taking were the personal attributes students mentioned in their salient theme syntheses. Many discussed passions as an intrinsic motivator for pursuing a career in this area and sticking with it, even when the outcomes are not always favorable. Intrinsic motivation is also connected to the pioneers' persistence that was seen as an underlying tenor of many

of their stories. Many students picked up on the fact that paving pathways in a new field can oftentimes be fraught with uncertainty, missteps, and a myriad of unintended outcomes. It is not surprising that an ability to persist in the face of obstacles is an attribute that unifies the pioneers' stories as a whole. Similarly, a propensity to take risks and pursue a new direction when appropriate is another theme that students mentioned often in their reflections. One of the recurring examples of how this is exhibited in the pioneers' stories is when looking across their career trajectories. Many of them were pursuing traditional engineering careers as faculty or industry professionals before making the shift to focus on engineering education. It is not surprising that open-mindedness was also an attribute some students perceived as consistent among the pioneers' stories because it speaks to a willingness to entertain and explore ways of thinking and doing that may be different from what you originally imagined. Such mindsets involve taking risks. A propensity to take risks enables someone to make a significant change.

The students' synthesis of the most salient themes was also related to conducting engineering education research. Networking and collaboration were the most commonly cited activities associated with conducting engineering education research. The pioneers' stories provided context on how the infrastructure that supports networking was established (e.g., ASEE and FIE conferences) and critical incidents that happened at or as a result of a conference. Many pioneers discussed others that they worked with as part of telling their stories. The importance of collaboration within and outside of engineering in order to conduct engineering education research (e.g., with colleagues in educational psychology) cannot be overstated. Such collaboration brings about awareness and knowledge of the entirety of the engineering education community.

Finally, reading the pioneers' stories gave the students an overview of the engineering education research landscape and the breadth of impact made by those in the field. Some students expressed having gained a better understanding of the scope of engineering education research (e.g., challenges this field is focused on addressing or insights on how researchers have approached these challenges in the past), while others saw their particular research interests throughout many of the pioneers' stories. This was particularly true for two of the students whose research interests focused on the persistence of women in engineering and the experiences of underrepresented groups. Another finding was the general knowledge that engineering education makes an impact in a plethora of ways, including individuals (e.g., impact on learners and instructors), infrastructure (e.g., development of publishing outlets and conferences), and policy.

DISCUSSION

Our discussion will begin by examining the similarities in the students' summaries of how reading the pioneers' stories impacted them personally. This will be followed by a discussion on how these

impacts compare with the influence of more traditional socialization mechanisms. The first section offers a discussion that is directly associated with the research questions posed in this study, while the latter shows how this work is connected to previous literature on this topic.

Impact of Reading the Pioneers' Stories

There are three themes among the students' responses on the impact of reading the pioneers' stories: 1) sense of validation in their career choice and belonging in a new field; 2) recognition of the knowledge, skills, and attributes that are necessary for success as an engineering education researcher; and 3) greater appreciation and understanding of engineering and engineering education research. The most prominent theme was a *Sense of Validation and Belonging.* While a few of the students talked about how reading the pioneers' stories provided them with an opportunity to reflect on their career path and their recent choice to pursue an engineering education career, many went further than this to express the sense of affirmation they experienced as a result of reading about the pioneers' path to and through engineering education. Expressions related to having concerns alleviated, relieving doubts, and the notion of finding your "place" within the field all speak to validation. Several students expressed a sense of belonging now that they are (proverbially) here in addition to affirmation of their past decision to pursue a career in a new field. For example, students talked about parallels in the ways they think with that of the pioneers' and explicitly stated that they felt "at home" in their new path.

The first theme focused on the impact on the students' perspectives of themselves. The remaining themes were externally focused. The second theme that emerged was the students' *Recognition of the Knowledge, Skills, and Attributes* that contributed to the success of the engineering education pioneers. Exposure to the pioneers' stories improved the students' knowledge of contributions made by many of the leading agents of change in engineering education. Such recognition implicitly sends messages about ways they should orient their behavior to improve the chances of being successful in this field. Examples included knowledge of the field leading to the development of a new research interest or research activities (e.g., proposal development) and communication, collaboration, and management as skills that are necessary for conducting interdisciplinary work. Elements of passion for addressing a particular problem and resilience in the face of challenges were among the most salient additional attributes students perceive as necessary for success as engineering education researchers.

The last theme that was consistent among the students' responses related to a *Greater Appreciation and Understanding of Engineering and Engineering Education Research.* For example, multiple students discussed a recognition and admiration for the valuable contribution of engineers and engineering education researcher as part of addressing educational and societal challenges. Other

students discussed the advances in their understanding of the engineering education field, the work of engineering educators/researchers that extend beyond the implied connection to teaching, and the context surrounding the field of engineering education. Such insights are useful for developing a foundational understanding of the field and for carving one's own path in it.

The three themes are distinct, but there are connections that can be made across the themes. The first theme is associated with the individual's choice to pursue a new career path in engineering education and how the pioneers' stories made them feel about this decision. The second theme reveals their perceptions about what it takes for them to be successful in this newfound space. The third theme corresponds to an increased awareness of the people and work that have laid the foundation for understanding the progress that has been made thus far, and insights on some of the challenges that they may be able to help address. These themes collectively address our research question, underscoring the potential for using the pioneers' stories as part of socializing graduate students into the field of engineering education.

Comparison with Traditional Socialization Mechanisms

One of the aims of this study was to document an innovative approach to socializing graduate students to the field of engineering education through the use of stories and explore the impact using such an approach. Students' insights on the impact of this approach serve as a point of comparison to some of the more traditional mechanisms for socializing graduate students. Existing literature highlights socialization models (i.e., linear, interactive; O'Toole, 1996), mechanisms for socializing students (e.g., knowledge acquisition, involvement; Weidman et al., 2001), and some of the outcomes of doing so. One of the themes in the students' responses reveals how the use of the pioneers' stories could serve as an alternative or supplemental way of achieving existing outcomes. The other two themes speak to the uniqueness of the impacts associated with the use of pioneer stories.

The theme that most closely aligns with the existing socialization mechanisms is an understanding of engineers and engineering education researchers' prior work. Knowing others' prior work is another example of the knowledge acquisition that takes place during graduate school (Weidman et al., 2001). We argue that the pioneers' stories are an alternative way to garner impressions about what it means to be a professional in the field. Validation of career choice and attributes associated with a successful engineering education researcher were not outcomes that were commonly mentioned when discussing traditional mechanisms for socializing graduate students. Graduate students learn the norms and values associated with a new profession through existing methods of socialization (Bragg, 1976; Boden, Borrego, & Newswander, 2011; Clark & Corcoran, 1986; Weidman et al., 2001), but the pioneers' stories are distinct as a socialization approach in exposing graduate students to the personal attributes (different from norms and values) of individuals that have

contributed to the collective success of the field. Lastly, networking is an important mechanism for socializing graduate students entering a new field. We acknowledge that reading the pioneers' stories is not the same as meeting the pioneers themselves. The simple introduction to names in conjunction with access and awareness of pioneer experiences provides a unique advantage for starting a conversation with them if the opportunity ever presents itself. Such opportunities have begun to emerge through sessions offered at the 2018 Frontiers in Education Conference and 2019 American Society for Engineering Education Conference & Exposition.

To summarize, the Pioneers Project is different from other socialization research in that it gives graduate students an opportunity to identify professional role models and develop their identity in the context of the discipline's historical figures. These particular mechanisms represent novel ways of enhancing graduate students' development and self-efficacy in the field. Through the use of stories about the early contributors to the field of engineering education, the Engineering Education Pioneers Project sheds light on past change efforts in engineering education as part of facilitating continued transformations in the field.

Implications and Recommendations

The Engineering Education Pioneers Project is a resource with vast potential to serve as a mechanism for introducing, expanding, and supporting those interested in the engineering education field. The stories offer an introduction to the field, including different pathways taken into the field, skills needed to be successful, and a clear differentiation between being an engineering educator (i.e., a good teacher) and conducting engineering education research. We foresee the stories being utilized by a variety of individuals in a variety of ways, including being embedded within an introduction to engineering education research course, advisor/advisee mentoring, and self-directed individual learning.

Reading all or a subset of the 47 stories provided by the project can provide depth and/or breadth about the field. A key step in deciding which stories to read is to first identify the goal for the particular individual or group. This study observed the benefits for graduate students newly enrolled in an engineering education doctoral program. The results for this group suggest that these stories can be used to provide a foundation for developing scholars enrolled in a degree seeking program specific to the field.

We project that these stories can benefit additional emerging scholars as well and that choosing appropriate stories to read is critical in the success of these stories having an impact. Such additional scholars include undergraduates who are unaware of engineering education as potential career path and faculty who have made the decision or are considering a shift in their research focus to engineering education. These two groups may both be looking toward a future career in engineering education and can use this resource as an introduction to the field. Some stories can be used

as a tool to recruit engineering students or faculty into the field by providing insights into what the field aspires to be and how developing scholars can contribute to the overall engineering education research agenda. Students enrolled in and faculty situated within units that do not have existing engineering education research expertise can supplement this missing component with some of the pioneer stories and learn about exactly what it is that engineering education researchers do for research. Additionally, these faculty may be advising undergraduate or graduate students who are interested in studying engineering education. Some stories provide mentors with information and insights about this field in which they were not formally trained.

Students and faculty alike can also use the list of pioneers as a resource to prepare for conferences, connect with experts, and build their network. Networking can be particularly important for those who have not yet begun to read the engineering education literature; for those who have, it can also provide a new perspective on the work of the pioneers.

Finally, the stories are also valuable for those who are already entrenched within the field by supplementing what is already known about these influential scholars through their research publications. It is important in any field to understand and appreciate the history of what has come before us, so that we do not lose sight of the fields overarching goals. The stories provide a history of the field through the lens of those who helped develop the field. Those learning from these stories are hopefully garnering an appreciation for what has come before them and the opportunities they have created for the next wave to further advance this field.

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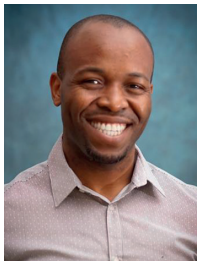

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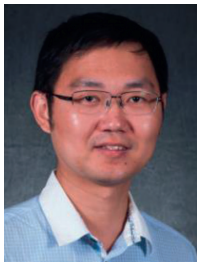

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