

Making an Impact on Engineering Education Communities: Learning from the Past and Looking Forward

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Introduction

The field of engineering education is constantly evolving, and understanding the nature of its transformation, as well as supporting related communities, has been the target of several studies and projects. This study builds on these prior efforts, in order to contribute to the understanding of past transformation efforts as well as facilitating continuing transformation. The analysis presented here is part of a larger study of the “impact trajectories” (contributions, influences, challenges, successes) of pioneers in the field of engineering education. For the purposes of this project, “engineering education pioneers” are defined as those who (1) are/were active (through research, practice, and/or service) in the area of engineering education; and (2) are recognized by members of the engineering education community as significant contributors to or shapers of the field of engineering education.

In this paper, we seek to explore in greater depth the nature of engineering education pioneers’ perceived contributions and impacts in engineering education, and what these contributions and impacts mean for the engineering education community. This analysis revealed that the large majority of responses referred to contributions or impacts related to either supporting and building engineering education communities, or defining the field of engineering education research. In addition to characterizing the nature of the reported contributions and impacts, we also examine these findings using a community of practice framework, in order to better understand the significance of these contributions to the field of engineering education and to inform future efforts to build and sustain engineering education communities.

Background

Understanding the nature of the evolving field of engineering education, as well as building and sustaining a community of scholars and practitioners doing this work, has recently been the focus of multiple studies and faculty professional development efforts. The transitioning nature of the field was brought to the forefront in the January 2005 special issue of the *Journal of Engineering Education*, in which community members reflected on the history, current state, and future of the discipline (e.g., work by Felder et al.,¹ Lohmann,² and Shulman³). Since that time, several scholars, including Jesiek et al.,⁴ Borrego & Bernhard,⁵ and Besterfield-Sacre et al.⁶ have examined various aspects of the field’s evolution and the simultaneous efforts to define the work and the community.

Efforts have also been made to build and sustain the community through faculty development experiences, often using a community of practice framework or approach. For example, the Institute for Scholarship on Engineering Education⁷⁻⁹ and the Rigorous Research in Engineering Education workshops¹⁰⁻¹⁴ each supported and scaffolded three cohorts of scholars in conducting engineering education research. A similar approach to scaffolding expertise while building community has also been used with engineering education graduate students, such as the work at Purdue University described by Adams et al.¹⁵

The Pioneers project is situated within this prior work in that it seeks to better understand the past, present, and future of the engineering education communities, while also providing professional development through networking new community members with more established members. To achieve our goal of better understanding the trajectory of the field and the community, we follow the lead of others' work in seeking to learn from the stories of key community members. For example, Mondisa et al. seek to "learn from others' stories" in their examination of change-makers in STEM education.¹⁶ Adams et al. also use stories and the idea of storytelling to explore the experiences of engineering education research scholars, and argue that through telling our stories, we are better able to support our community and share knowledge, experiences, and lessons learned, which then helps strengthen our community and its shared practice.¹⁷

Clearly, much thought has been put into understanding the evolving nature of the field of engineering education, as well as into building and sustaining the communities doing this work. The present study seeks to explore in greater depth one aspect of the trajectory of this field and the roles played by the individuals involved; that is, the nature of the pioneers' perceived contributions and impacts in engineering education, and what those contributions mean for the related communities.

Community of Practice framework

This study uses a community of practice lens to help understand how people work in the space of engineering education. We use Wenger's concept of a community of practice (COP), defined as a combination of three dimensions: a specific domain of knowledge or *joint enterprise*; *mutual engagement* of a group of people who are interested in this enterprise and build relationships through interactions; and a *shared repertoire of practice*.¹⁸⁻²¹

It is important to note that although the terms "engineering education community" or "engineering education research community" are frequently used, we recognize that, rather than being one large, homogeneous group, this "community" in fact encompasses many communities, several of which overlap or are embedded within other communities, and individuals often belong to more than one. For example, one might be a member of a COP focused on research or teaching practice, in addition to being a member of a department- or institution-based COP, while also being part of a national-scale COP such as the American Society of Engineering Education. We argue that all of these might be seen as communities of practice, and our pioneers' stories often reference multiple communities. In this paper we look at the pioneers' discussions of community broadly, recognizing that these communities often overlap and influence each other, and the pioneers' work over the years may cross multiple community boundaries.

Project-wide research questions

As mentioned above, this analysis is part of a larger study of the "impact trajectories" (contributions, influences, challenges, successes) of pioneers in the field of engineering education. The present analysis centers around one aspect of the pioneers' impact trajectories, namely, attempting to characterize and understand the pioneers' own perceptions of the

contributions and impacts to the field that they feel they have made in the course of their careers. Specifically, we ask:

- What do the pioneers feel have been their most important contributions and/or impacts in the field of engineering education?
- What can we learn about the significance of these contributions by examining them in terms of communities of practice?

Data collection

Semi-structured interviews were conducted with 47 pioneers (in person, by telephone, or via Skype). All interviews followed the same interview protocol, which included six required questions and several optional follow-up prompts, allowing the interviewers to clarify or probe more deeply where appropriate. Most of the interviews (39 of the 47) were conducted by graduate students or early-career faculty interested in engineering education as part of a professional development program.²² The remaining eight interviews were conducted by a researcher on the project team.

All participants were provided with a participant information form prior to the interview, which included information about the project and the following statements:

“Your interview transcript will also be analyzed as part of our research effort to better understand transformation in engineering education. If we choose to use a quotation from your response in a publication, we will first give you the opportunity to review and approve the quotation.”

At the beginning of each interview, participants were provided an opportunity to ask questions and confirm their consent. As promised, all participants quoted in this paper were given an opportunity to review a draft of this paper prior to final submission for publication.

The purpose of these interviews was to elicit pioneers’ views on their career trajectories, and in part included questions about the contributions or impacts that participants felt they had had over the course of their careers. This paper presents findings related specifically to that subset of interview data.

Study participants

To recruit study participants, we sought nominations from multiple communities related to engineering education:

- American Society for Engineering Education’s Educational Research and Methods Division (ASEE ERM), ASEE’s Minorities in Engineering Division (MIND), ASEE’s Women in Engineering Division (WIED), Women in Engineering ProActive Network (WEPAN), National Action Council for Minorities in Engineering (NACME), National Academy of Engineering’s Center for the Advancement of Scholarship on Engineering Education (NAE-CASEE), National Science Foundation

- Editors of engineering education journals
- Chairs of engineering education departments/schools
- Engineering education e-mail lists

Through this process, 93 people were nominated by more than 30 individuals. From this pool, the project team and advisory board selected pioneers to be invited to participate, through a process involving multiple criteria, including:

- number of nominations
- diversity
- year of entry into engineering education
- engineering education-related awards, and
- type(s) of contributions to the field.

Ultimately, 47 people were interviewed, with an emphasis on pioneers who were near retirement or had already retired. Resources limited the number of pioneers who could be interviewed and profiled. Further, not all invited pioneers were interested or able to participate. We acknowledge that this is just a sample of the many people who have substantially contributed to engineering education and hope that this work can be expanded to include more of them.

Data analysis

All 47 interviews were audio recorded and transcribed. Using qualitative analysis software (ATLAS.ti), the transcripts were coded for the contributions and impacts reported by the pioneers, drawing primarily on responses to the question, “As someone whom others regard as a pioneer, how would you describe your contributions or impact in engineering education?” The interview protocol used both “contributions” and “impacts” in the questions and prompts related to this topic. Participants typically chose one term or the other in their responses; therefore, their responses were coded as either “contribution” or “impact” along with codes pertaining to the nature of those contributions or impacts. However, in the course of our analysis it became clear that the distinction between contribution and impact was not meaningful, and more salient categories emerged that included responses coded as either contributions or impacts.

The first round of coding was conducted by one researcher, with regular check-ins and discussions with a second researcher. A subsequent round of coding, focusing more specifically on mapping data to the COP framework, was conducted jointly by two researchers, with regular check-ins, comparisons, and discussions.

Findings

Qualitative analysis of the interview transcripts yielded a total of 156 comments in which all 47 participants discussed their perceived contributions to or impacts on the field of engineering education. Most of these comments (95%) fell into the following categories: (1) supporting the community; (2) defining the field; and (3) changing teaching practice. These large categories were further analyzed to discover nuances within these types of contributions and impacts (see Table 1).

Table 1. Pioneers' reported contributions/impacts. Subcategories are shown only for the focal category in this paper, Supporting the Community.

Category	Subcategories	# of statements
Supporting the Community	Facilitating others' success	35
	Service to the community	14
	Building the community	13
	Role model	8
	Funding	8
	Leadership	5
	Helped students	4
	<i>Subtotal:</i>	87
Defining the Field		22
Changing Teaching Practice		39
Other	E.g., specific curricula, textbooks, programs, etc.	8
Total # of statements coded as Contributions or Impacts		156*

*Some responses were coded with multiple codes.

The large majority of the perceived contributions or impacts were community-focused, having to do with supporting the engineering education research community or defining the space of engineering education research, rather than focusing on specific, personal accomplishments (e.g., an influential publication). This highlights the collaborative nature of this work and the culture of the community, as well as pointing to the evolutionary stages of the field during the time of these pioneers' careers.

Facilitating others' success

In this analysis, we focus specifically on the most frequently cited type of contribution or impact: facilitating others' success. Across the transcripts, 35 comments (22% of all contribution/impact-related comments) from 24 pioneers referred to contributions or impacts the pioneers felt they had achieved related to facilitating other scholars' success. In analyzing the ways in which participants talked about facilitating others' success, subthemes emerged, indicating a variety of roles that community members can play, as well as different kinds and scales of intended impact. While many pioneers made their contributions from positions of leadership—e.g., in their institutions or at national organizations like the National Science Foundation (NSF)—this was not universally the case. Pioneers varied in whom they sought to support and for what kinds of activity. Many focused on supporting faculty in research and/or teaching activity in engineering education. Some pioneers focused on providing moral support—e.g., encouragement and empathy in the face of the challenges associated with doing engineering education work. Others emphasized what we call intellectual support, providing guidance on relevant methods, tools, literature, theory, etc. Pioneers mentioned other kinds of support, still, including funding for innovative scholarship and practice in engineering education.

To organize this paper, we focused on another dimension of variation in the pioneers' accounts of facilitating others' success. We categorized the accounts based on the scale of the intended primary impact. Although the ultimate beneficiaries of all of the described efforts were

individuals, some pioneers looked to achieve impact at scales larger than one person at a time. For instance, some pioneers described efforts to establish or change institutional organizations or structures (e.g., a department, program, or college of engineering). Other accounts emphasized a national scale of impact (e.g., cohorts of NSF program awardees). We explore the nature of each of these levels of intended impact through the pioneers' own words below.

In some way, all of the pioneers who participated in this study undoubtedly contributed to the success of other engineering education community members. The present analysis focuses on those pioneers who characterized their contribution or impact primarily in terms of facilitating others' success, privileging the pioneers' accounts over our interpretations of their stories as researchers (see Table 2). As such, this analysis also excludes pioneers who described facilitating others' success but did not identify those efforts as their primary contributions or impact in engineering education.

Table 2. Pioneers quoted in this paper, with titles and affiliations at time of interview.

Name	Titles and Affiliations
Robin Adams	Associate Professor, School of Engineering Education Purdue University
Rebecca Brent	President, Education Designs, Inc.
John Cowan	Emeritus Professor of Learning Development Open University, UK
Denny Davis	Emeritus Director, Engineering Education Research Center Emeritus Professor of Bioengineering & Engineering Education Washington State University
Lawrence Grayson	Visiting Scholar, School of Philosophy, The Catholic University of America
Roger Hadgraft	Deputy Dean of Learning & Teaching, School of Engineering and Technology Central Queensland University, Australia
Sue Kemnitzer	Deputy Division Director of Engineering & Centers National Science Foundation
Louis Martin-Vega	Dean and Professor, College of Engineering North Carolina State University
Barbara Olds	Associate Vice President for Educational Innovation, and Professor of Liberal Arts & International Studies Colorado School of Mines
Michael Pavelich	Emeritus Professor Colorado School of Mines
Percy Pierre	Vice President Emeritus and Professor of Electrical & Computer Engineering, Michigan State University Director, Sloan Engineering Program
John Prados	Vice President and University Professor Emeritus University of Tennessee-Knoxville
Sheri Sheppard	Professor of Mechanical Engineering Co-Director, Center for Design Research The Burton J. & Deedee McMurtry University Fellow in Undergraduate Education Stanford University
David Voltmer	Professor of Electrical & Computer Engineering

	Rose-Hulman Institute of Technology
Karan Watson	Provost and Executive Vice President for Academic Affairs Texas A&M University
Charles Yokomoto	Professor Emeritus of Electrical & Computer Engineering Indiana University-Purdue University Indianapolis

Individual level

Eleven of the pioneers emphasized the ways in which they had facilitated others' success at the individual level, often through one-on-one, personal interactions. These interactions were described as being supportive in terms of providing intellectual support, moral support, or a combination of the two. These pioneers helped individuals succeed in a variety of activities, mostly some combination of research and teaching work.

Intellectual support, research work: By intellectual support, we mean support taking the form of guidance on relevant content, pedagogy, or research techniques. For example, Sheri Sheppard spoke about her work in "facilitating people getting up to speed in this," and "helping people learn to do the work at high quality." She gave the example of mentoring a fellow engineering professor "on how you do this other kind of writing. And how do you make arguments now on a different kind of data than she's ever been used to working with." In other words, Sheppard has leveraged her own experience and knowledge of doing and writing about engineering education research to help others begin to do this type of work.

Similarly, Charlie Yokomoto referred to the support he had given to engineering education researchers through helping colleagues write successful grant proposals:

"Because of my activities in engineering education I did a lot of work with other faculty members in teaming up there with the Department of Education. Classroom development proposals. I did a lot of work helping people word it correctly, so that the wording is read by people who are experienced in classroom design and assessment."

Denny Davis also reflected on the support he has provided for colleagues pursuing engineering education research projects:

"Based on my convictions, I just feel like I need to be helping others be successful. So, I think my role has been one of trying to facilitate the success of others. For example, at Washington State, I attempted to help younger faculty be accepted for doing this kind of work. Networking them with one another, being an advocate for them, helping them with grant proposals, and so on. So they who had the potential to go much further than I, if they could get the training off to a good start, I could have much more impact by doing that."

Intellectual support, teaching: In addition to supporting colleagues' research efforts, individual intellectual support can also focus more on teaching or practice. For example, David Voltmer recalled that he was a "champion of a certain kind of laboratory work," while Rebecca Brent spoke about her involvement with engineering teaching workshops:

“I think [my contribution] is pretty much out there in the workshop work. ... I think I work with people really well one-on-one. I think I have developed a lot of the materials that we use and brought in a lot of ideas. So I’m more of a behind the scenes person than an out there in front person.”

Similarly, Michael Pavelich commented:

“I hope [my contribution] is to have documented the importance of these learning taxonomies and to take them seriously and understand them fully, and then models of how to implement that kind of thinking in the classroom, and then finally ways of measurement that make sense or that really speak to the point of improving along that scale of the taxonomy. So, you know, basic research things. Find a good goal. Improving the thought process of the students. Find a good model to help you design things. Do the design and then find a good way of measurement and then do a feedback loop on all of them. Hopefully if anything, our work modeled all of that and gave people a way to spring forward from that. ...For many years after I retired I continued to do workshops on these taxonomies and really focusing on how do you get people to understand critical thinking better. ...But through all of this I have always done TA training, really getting incoming TAs to understand those taxonomies, understand how the course of the teaching fit in and then modeling how they should be teaching to their students and then to have them try to do some quick practice teaching to get them ready. And I did that for several years for Mines after I retired and then I quit.”

Moral support: Individual support through one-on-one interactions can also take the form of moral support, by which we mean focusing on encouragement, reassurance, or providing positive feedback and perspectives, rather than on the specific content or practices of the work being done. For example, Roger Hadgraft commented that his contribution has taken the form of “more consciously nurturing others in the process.... Nurturing younger people as they came into this business and encouraging them and helping them to connect with other people, and all those things.”

Other pioneers also made comments along these lines when reflecting on their careers. For example, John Prados recalled the individual support he had given through his work with the Engineering Education Coalitions:

“Hopefully, some of the young people that we worked with in the Engineering Education Coalitions, hopefully we were able to give them encouragement and to help them to move forward. ...They were people who were already on the path, and I think our function was not particularly setting them on the path, but just helping to provide and encourage support for what they were trying to do.”

The support highlighted here has less to do with helping these individuals understand the work or convince them to try it – they were “already on the path” – and more to do with general encouragement to stay on that path.

Lawrence Grayson also spoke about encouraging or enabling individuals to persist in the work, commenting that:

“There really are people there who really want to do a great job, but they need somebody to point the direction, to show them they’re not alone, to help them along, to a large extent. And to give them the motivation and give them really just the opportunity to do something, and the encouragement. . . . My philosophy is always, if you have somebody with an idea, and he wants to do it, set up a system so that, you know, clear the way for him, effectively. Do the blocking, let him run. Or her. Let him run, and do your thing. And you help clear the obstacles, and you get some great results.”

This type of support can be both helpful to the individuals being supported and also gratifying to those giving the support. For example, Karan Watson talked about watching the outcomes of her support emerge over time: “Over a cycle of several years, I usually find out what [former students] are doing and how they’re doing. I also run into students . . . at various conferences or events or something . . . and they say I’m their ‘grandmother.’”

Individual support can also be a mix of intellectual and moral support, as illustrated by Barbara Olds’ reflection on her contributions:

“[My legacy] involved working more with junior faculty in a variety of places through being engaged with the folks in places like Purdue and Virginia Tech later in career. But earlier, supporting people, like [through] ASEE, working with people who were junior [faculty], trying to help folks along their career paths they’ve chosen and support the publications and the research and other things.”

For each of these pioneers, supporting new scholars in the field has been an important part of their careers, and they have accomplished this primarily through personal interactions with individual colleagues.

Institution Level

Facilitating others’ success can also be done through efforts that target whole groups of individuals, such as a group of faculty in a department or across an institution. For example, rather than focusing on one-on-one interactions with single individuals, one might help colleagues succeed by creating a department-, college-, or even institution-wide culture that can support everyone pursuing engineering education work within that context. Participants who reported working at this scale felt that their greatest contributions had to do with their efforts to institutionalize certain approaches to and practices in engineering education, and subsequently building capacity in the field by impacting future faculty and their students.

For example, Robin Adams reflected on the work she was able to do as an early faculty member helping design foundation courses in the new doctoral program at Purdue’s School of Engineering Education:

“It was a really great time to come here because I got to play a really big role in what does this program look like. . . . a lot of it had to do with pulling from my experiences, pulling from the Institute [for Scholarship on Engineering Education] in terms of, what are the challenges I’ve seen other people experience and how can we sort of transition them into this place? So it’s one thing to provide a path; it’s another to kind of have water holes and

community things along the way. And so when we developed the curriculum for the program, I think people sort of scratched their heads, because it had more philosophical, sociological foundations, and it wasn't like, class on assessment, class on best practices in teaching, and class on research. It was really this thing of like, if you're going to do engineering education, what does it mean to become one, and how do you sort of create that developmental pathway? How do you connect to where we've been and where we're going, and what are all the things that shape this, in terms of thinking about the research or the impact that you want to have?"

John Cowan commented on the work he has done to reform engineering education practices at the departmental or institutional level, not only at his home university but also at numerous institutions around the world:

"My biggest contributions have been at the grassroots. I've only written two books and I'm not one of the big name personalities, but I've gone into situations and worked there with teachers, with my colleagues in my own department and in places around the world. We've changed things. ...I would say that my contribution has been getting into grassroots activity and showing the people that are involved there how they can change things, how they can evaluate them, and how they can do without me. I mean, the most important thing is, when I go away, are they going to manage without me now? And are they going to go on being creative, and are they going to have stories to tell me about, 'We've done this,' and 'We've done that,' that they're not following John Cowan. I mean, I see myself as a facilitator nudging them to be the best that they can be and then quietly bowing out and letting them be the innovative people, and then I can always go to another place and work in another grassroots activity."

Although this type of impact can be accomplished in a variety of ways, from several different positions within or outside of the department or institution, some pioneers recognized that holding an administrative position can facilitate doing this type of supportive work. For example, Louis Martin-Vega talked about his visibility as an administrator, and how his actions in that visible position can send messages throughout the department or college:

"I would want to think that as an administrative leader in academia, that the fact that I feel this is important, that it's something that people do need to pursue and enhance, is a contribution. That every faculty member in our college, our department heads, they know where I stand on this. Not because I stand up and give speeches about it all the time, but simply the commitments that you make. If I'm involved with the Engineering Deans Council, and I'm involved with the American Society of Engineering Education, and you play leadership roles in these areas, and you are involved in diversity committees, and you are involved in symposiums and workshops in engineering education, and you try to provide support and funding for people in your college that are doing things along those lines, you're sending a message out, right?"

Similar to the pioneers discussed in the previous section, these pioneers feel strongly about helping colleagues enter and succeed in engineering education work. They too have sought to provide what individual scholars need in order to be successful; however, their efforts to provide

such support have been aimed at groups of scholars rather than individuals, often with the goal of institutionalizing norms and practices to benefit both current and future scholars.

National Level

Providing funding for and/or recognizing engineering education scholarship: Some of our pioneers identified their leadership role in awarding funding for engineering education scholarship as one way in which they helped others succeed. For example, Susan Kemnitzer and Louis Martin-Vega described how their respective efforts at the National Science Foundation eventually resulted in funding programs dedicated to engineering education, advancing work in the community. Similarly, Percy Pierre described how, as director of the Sloan Engineering Program, he supported pre-college engineering education efforts for minority students. Although these pioneers helped fund different kinds of engineering education work (research, teaching, and learning), they all described their influence more in terms of legitimacy for engineering education than in monetary terms.

Kemnitzer's account focused on supporting early-career faculty through an NSF program that was the precursor to the current CAREER program. She recalled how the first award of this kind to a faculty member engaged in engineering education work was a significant step toward the field gaining legitimacy at the national scale. She described how the prestige and visibility of these awards help "establish engineering education research as a bona fide field, and get it recognized more within NSF, and also, of course, within each engineering school."

Similarly, Martin-Vega's remarks emphasized that NSF awards were much more than just funding: "The thing about NSF is that even when it's basically seed money, everybody is going to watch and listen, because when NSF says, 'We're going to do something,' it is pointing the way to the future." He described how grants are also about developing credibility for engineering education work, and he credited others at NSF who helped establish the Division of Engineering Education and Centers as being "the catalysts that got engineering education to another level...where there would be much more credibility and understanding that this is a very legitimate research endeavor."

For Martin-Vega, NSF was not the only setting where he worked to lend engineering education legitimacy and visibility on a national scale. He described how his efforts to promote and support engineering education work on campus at NC State might have influence beyond the local institution. He expressed the hope that his local work paved the way for peer institutions to follow suit and invest in engineering education: "I want to think that [my work was] maybe something that other people can point to and say, 'Well, you know, look at what they do at NC State.'"

Percy Pierre similarly described his work supporting the success of minorities in engineering through a variety of leadership positions, including at the National Academy of Engineering and the Alfred P. Sloan Foundation. From these leadership positions, Pierre described how he helped establish what are now longstanding programs for supporting minority students in engineering, including the National Action Council for Minorities in Engineering. He described his efforts, like Kemnitzer's and Martin-Vega's, as aiming for national-scale impact. His accounts of his work with the Sloan Foundation echoed Kemnitzer and Martin-Vega's remarks about leveraging

the prestige of NSF. Pierre described how the Sloan Foundation's reputation caused a school board considering starting a minority engineering magnet school to take notice:

“The school board was impressed. ‘Oh, that foundation in New York thinks we should do something different, so let's do it.’... They listened to us because we were from the outside... The Sloan Foundation had leverage.”

Pierre did go on to stress, however, that the reputation and leverage needed to be coupled with sound planning: “It's not just the name [of the foundation]. You had to design the school with the right curriculum. You had to place it... within an existing high school that had a principal who really supported it and solved every problem they had.”

Discussion

The engineering education pioneers described many different ways in which they helped facilitate others' success. We next examine their accounts in terms of Lave and Wenger's three dimensions of community of practice (mutual engagement, joint enterprise, and shared repertoire of practice), in order to better understand not only the significance of the pioneers' impact but also how they went about achieving impact.

Individual level

In the pioneers' discussions of facilitating others' success through one-on-one interactions with individuals, multiple COP dimensions are touched on, to varying degrees. In each instance, the pioneer describes participating in *mutual engagement*, interacting and building relationships with colleagues. Both moral support and intellectual support involve this type of interaction, although mutual engagement is particularly obvious in the personal connections inherent in moral support. Mutual engagement takes place within the context of the *joint enterprise*; that is, the work of engineering education, whether in terms of research or practice. Individual support, particularly of the intellectual type, also corresponds to the *shared repertoire of practice*, since it often takes the form of guiding colleagues in the practices of this COP; e.g., what we do and how we do it, pedagogy, concepts, theories, research techniques, or language and discourse. The specific repertoires and practices that are supported vary according to which sub-communities the pioneers move within (e.g., communities based on a research or teaching focus, geography, academic position, etc.). Pioneers quoted above described attending to a wide range of practices—e.g., Yokomoto and Davis attending to preparing grant proposals, Brent and Voltmer attending to teaching undergraduate engineering. In summary, in the pioneers' descriptions of the individual level support they have provided, we find elements that correspond to all three dimensions of a COP, but falling more heavily into the dimensions of mutual engagement and shared repertoire of practice.

Institutional level

Pioneers who provided support at the departmental or institutional level also participated in *mutual engagement*, but in a slightly different way than those working at the individual level. Rather than one-on-one interactions, their engagement efforts have taken forms such as community maintenance, being a trusted partner, or creating relations among community

members – with the community in question tending to be bounded by a department or institution. Institutional level support strongly corresponds to the *joint enterprise* dimension of COP, as these pioneers have worked to define and institutionalize what this domain of interest includes and what it means to do engineering education work, such as what matters, what is important, and what types of competence distinguish community members from other people. Adams' quote above describes her direct influence on defining how the joint enterprise of engineering education research is presented to graduate students new to the field and research community. These efforts also include supporting others in mastering the *shared repertoire of practice*, including concepts, research, and teaching practice, as a means of enacting the joint enterprise. Cowan describes his focus on showing stakeholders in engineering education how to assess their programs, to ensure success sustained long after his involvement. As with individual level support, we find that pioneers' stories of providing institutional level support include elements of all three COP dimensions; however, this type of support appears to focus most heavily on the joint enterprise dimension.

National level

From a COP perspective, the pioneers who aimed for national-scale impact had the most complex accounts, invoking multiple communities and the unique opportunities to negotiate joint enterprise that came with simultaneous membership in them. All of our pioneers can be considered members of the umbrella community of practice associated with engineering education. In addition, Kemnitzer, Martin-Vega, and Pierre were members of respected, national funding organizations (NSF for Kemnitzer and Martin-Vega, and Sloan for Pierre). These pioneers recognized how this overlap of memberships gave them unique opportunities to advocate for engineering education work and the communities associated with it. They intentionally leveraged the prestige of their national organizations to push other communities like engineering schools (Kemnitzer, Martin-Vega) and secondary school boards (Pierre) to accept engineering education as legitimate work. In this sense, we argue that these pioneers were influential in the negotiation of these communities' respective joint enterprises. Furthermore, in Kemnitzer's case, the funding agency was both a source of influence with external communities like colleges of engineering but also the site of internal negotiation of joint enterprise; her quote above describes how she argued for engineering education's legitimacy within NSF, in addition to within schools of engineering. Ultimately, these three pioneers' efforts were directed toward providing the national engineering education community the resources and space to coexist and develop in the context of the more established communities in which its members work— departments, campuses, etc.

In summary, with the focus on facilitating others' success, to some extent, all of the pioneer accounts featured in this paper imply at least some amount of mutual engagement within one community or another. However, the form and extent of this engagement varied by pioneer. More interestingly, depending on who each pioneer was seeking to support and how, their accounts describe differential emphases on joint enterprise and/or shared repertoire. In examining these variations, we observe that the pioneers (and those whose success they seek to facilitate) work in multiple, often overlapping communities of practice, both those that fit under the umbrella of engineering education and those that lie outside of it. These communities of practice each have their own joint enterprises and shared repertoires of practice.

Boundary work

Finally, many pioneers described how they attended to the boundaries between these communities of practice, especially between communities that embraced engineering education work and those that regarded such work as less legitimate. Some of this work can be seen as what Wenger calls “brokering.”²⁰ As Wenger states, “Some people act as brokers between communities. They can introduce elements of one practice into another,” working as boundary spanners, roamers, outposts, or pairs (p. 235). We see this brokering when pioneers talk about collaborating with colleagues in other disciplines (such as education), sharing knowledge from one community with another, or gathering new ideas at a conference or workshop and championing them in their home communities. Wenger also goes on to describe “boundary interactions,” including boundary encounters, boundary practices, and peripheries (p. 236–7). These activities and interactions are seen in the stories of pioneers who talk about visiting other settings and immersing themselves in new ideas and practices, networking and fostering relationships among people from diverse communities, or creating welcoming spaces at the peripheries of communities to facilitate access across boundaries.

The evidence of this work at the boundaries emerged through grounded qualitative analysis of the interview data, and as such was an unexpected and interesting finding. While the scope of the present analysis does not allow for a thorough examination of this boundary work and its significance for engineering education communities, our findings do suggest that this is an area which merits further exploration in the future.

Limitations and implications

Limitations: Because of the nature of the methodology of this study, this analysis does not seek to generalize about the engineering education community at large. The data analyzed here are drawn from a relatively small number of participants; however, these participants were intentionally targeted in order to represent the experiences of a wide range of individuals and roles within the broader community. Therefore, we anticipate that the themes that have emerged from this sample likely apply to others doing this type of work, and may spark conversations about additional, diverse experiences and perspectives. The findings presented here are also limited in that they represent a preliminary analysis of a very rich data set, and we recognize that there is much more to discover.

Implications: The findings of this analysis have implications for those in multiple positions within the communities of practice connected to engineering education. New engineering education scholars who are just entering the field can benefit from knowledge about the history and trajectory of the field and its members, which may serve as a guide for navigating the field and becoming a core participant in relevant communities. Current engineering education scholars can gain perspective on how to help new scholars enter and navigate the community, as well as how and why to continue supporting the community. Finally, scholars in other similar (e.g., new and/or interdisciplinary) fields may find that their efforts are informed by our findings regarding what works or what is important for the transformation and sustainability of an evolving field and community.

Conclusion

In this paper we sought to better understand the history and trajectory of transformation in engineering education, at least in part, by examining one portion of the stories of pioneers in the field. By focusing on the pioneers' perceived contributions and impacts over the course of their careers, we were able to identify areas which they see as important aspects of their work; in particular, supporting and building the community through facilitating others' success. As noted above, the "community" in question may vary from pioneer to pioneer, reflecting the diversity and multiplicity of communities at work under the larger umbrella of what is commonly referred to as the engineering education community. However, regardless of which specific community appears in each pioneer's story, our findings show that across participants, the ways in which they describe their actions and intentions provide evidence that they are working within communities of practice.

We argue that the prominence of community maintenance work (i.e., facilitating others' success) in these pioneers' career trajectories demonstrates how critical this work is for the field of engineering education. Granted, these efforts are important for any community of practice, but they are perhaps even more necessary, and might need to be more visible and deliberate, for a COP that is relatively young and still being defined and understood.

Our findings also highlight the diversity of ways in which community members can work to facilitate others' success. For example, one message coming out of the pioneers' stories is that, although those in positions of power can do certain things that others cannot, everyone from graduate students to faculty to administrators to funders can contribute to building and sustaining their communities in various ways. Whether working at the individual, institutional, or national level, community members have found – and will continue to find -- a wide range of methods to support those doing engineering education work.

Certain aspects of the pioneers' experiences may not apply in precisely the same way for new or incoming scholars, due to the evolving nature of the field. The contexts in which some of our pioneers began their careers, and the challenges they faced, differ in many ways from what engineering education scholars find today. However, certain themes hold true, including the importance of actively and deliberately working to build and sustain the communities of practice within which we move. In addition, the pioneers' stories are informative for the community broadly, in that knowing where the field came from and why it has followed certain trajectories, as well as knowing that its evolution did not happen on its own or by chance but rather required deliberate work by many people, will provide grounding for those who will be carrying the field forward.

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