Becoming an Engineering Education Researcher: Finding Pathways toward Interdisciplinarity

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Abstract
Interdisciplinary thinking is gaining momentum as an important topic for empirical investigation, particularly in regard to how crossing disciplinary boundaries can enrich teaching and learning across fields. This paper focuses on one particular interdisciplinary setting: engineering education. Using data from semi-structured interviews with engineering education researchers, this study explores what it means to work in an interdisciplinary space and the process of becoming an interdisciplinary scholar. Findings emerged regarding the nature of the pathway to expertise in engineering education research, including entry points, factors that facilitate working in this field, strategies for successful interdisciplinarity, and the nature and role of community throughout scholars' pathways. Given the growth of interdisciplinary work, we anticipate that our findings will have applications beyond our context, in other interdisciplinary fields.

Introduction

Interdisciplinary thinking is not a novel idea, but is gaining momentum as an important topic for empirical investigation. One "call to action" to facilitate interdisciplinary work identifies four driving forces: the inherent complexity of nature and society, the desire to explore problems and questions that span disciplines, the need to address societal problems, and the power of new technologies (CFIR, 2005). This highlights a need for researchers who can think and work at the interdisciplinary interface (Gidjunis, 2004; Pfirman et al, 2005; Young, 2001). However, despite increased attention given to interdisciplinarity as a goal, there remains much to understand about the nature of interdisciplinary work and who is doing it (e.g., Bromme, 2000; Gidjunis, 2004; Pfirman et al, 2005; Young, 2001). Because of the broad interest in interdisciplinary work, research on interdisciplinarity in one context may provide useful insights for other settings.

This study focuses on one particular interdisciplinary setting: engineering education, an interdisciplinary space at the interface between engineering and education disciplinary perspectives. Engineering education research often involves drawing on theories and research methods from education and applying them to investigations of teaching and learning in engineering contexts. There are also signs that engineering perspectives may be influencing education research methods such as design research (Edelson, 2002). Increasing numbers of researchers have been crossing boundaries into engineering education, resulting in important findings and improvements in the way engineering is taught at the college level.

This study is an exploration into what it means to work in the interdisciplinary area of engineering education research and the process of becoming an interdisciplinary scholar. Our

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ultimate goal is to support efforts underway to build capacity in engineering education research, which necessitates understanding the interdisciplinary scholar experience. These efforts include the emergence of long term programs such as engineering education departments (e.g., Purdue University, Virginia Tech) and short term programs such as the Institute for Scholarship on Engineering Education (ISEE). We anticipate that the findings of this study will enable us to more broadly support those who enter engineering education research and construct identities within this interdisciplinary space.

Theoretical Framework

Previous research illustrates the characteristics of interdisciplinary spaces and the work done within them. For this study, interdisciplinary work is being defined as research done by a single individual, in which the researcher steps outside the borders of his or her field and draws from multiple disciplines and perspectives (e.g., Klein, 1990, 1996; see also Frost & Jean, 2003). Galison (1997) uses the term "trading zones" to emphasize the places where various subcultures meet and interact. Similarly, interdisciplinary work is often characterized by phrases such as "boundary crossing," "border crossing," "puddle jumping" and "translation" (e.g., Barley, 2001; Klein, 1990, 1996; Lauzon, 1999; Thames & York, 2003; Young, 2001).

While existing literature provides pictures of interdisciplinary spaces, and suggests signifiers of identity for those who work within those spaces, it is not clear how these generalizations play out in engineering education. In addition, an opportunity exists to contribute to the existing body of literature by focusing on the process of becoming an interdisciplinary scholar – examining the pathways into interdisciplinary communities of practice and the process of constructing interdisciplinary identities.

Using the above ideas to define interdisciplinary spaces, a question emerges: How do people enter, navigate, and work in these spaces? If entering an interdisciplinary field is viewed as entering a new community of practice, the notion of legitimate peripheral participation (Lave & Wenger, 1991) provides a useful framework. From this perspective, newcomers to a community of practice begin participating in an "apprentice" mode, allowing them to gradually increase their participation in ways deemed legitimate by the community. As participation increases, they become socialized into the new community (Barretti, 2004; Cook et al, 2003), and their identification with the community evolves. As Lave and Wenger (1991) observe, "Moving toward full participation in practice involves not just a greater commitment of time, intensified effort, more and broader responsibilities within the community, and more difficult and risky tasks, but, more significantly, an increasing sense of identity as a master practitioner"(p. 111). To explore such identification, the stories people tell about themselves may be utilized as rich and valid sources of data for investigating and interpreting identities and identity pathways (Barley, 2001; Lave & Wenger, 1991; Personal Narratives Group, 1989; Sfard & Prusak, 2005).

The use of people's stories as research data can be further supported by looking at the history of using such data across disciplines. Storytelling has long been recognized as a way of making meaning through discourse, as private experiences are translated into publicly negotiated forms (e.g., Bruner, 1986, 1991, 1992, 2002; Egan, 1995, 1999). Using stories as research data is an established tradition in many fields, such as cultural anthropologists' systematic collection of

oral histories to illuminate people's experiences, often focusing on giving voice to those who have historically been silenced (e.g., Erickson, 2003; also illustrated in *The Journal of the Oral History Society*[6] and the *Journal of American Folklore*[7]). Educators have used storytelling and autobiographical writing for many purposes, such as helping students gain deeper understandings of personal experiences, learning processes, and social contexts (e.g., Butler & Bentley, 1996; Karpiak, 2000; McCabe, 1997; Paley, 1990). Storytelling is also being used in engineering education research. For example, the NEXT (Narratives supporting EXcellent Teaching) website, developed by Turns (2006) and her colleagues, features stories of engineering educators' teaching challenges and how they resolved them. The stories allow engineering educators to identify with colleagues in similar situations, learn how others have dealt with challenging situations, and find guidance in resolving their own teaching challenges. Given this rich tradition, eliciting and sharing stories appears to be an appropriate method for meeting this study's goals of illuminating pathways into and through the community under study, illustrating successful strategies for working in this community, and supporting scholarship in engineering education.

Methods and Data Sources

For this exploratory study, an initial sampling of members of the engineering education community was interviewed. Participants included ten individuals at various levels of membership in the engineering education research community that were 1) known to work across multiple disciplines, 2) committed to this kind of interdisciplinary work, and 3) recognized as members of the community (see Lattuca, 2001). Participants were purposefully targeted to represent multiple points along interdisciplinary pathways and varying levels of membership in the engineering education research community.

Semi-structured interviews were used to engage participants in conversations about their interdisciplinary work (Sanjek, 1990; Spradley, 1979). Participants were asked to tell their "stories" (Lave & Wenger, 1991; Sfard & Prusak, 2005) about how they became interested in engineering education, how they began doing this type of work, what challenges they faced and how they overcame those challenges, and what advice they would give to others who wish to enter the field.

Each participant was interviewed once, for approximately one hour. Interviews were audio recorded and transcribed. The first two authors developed themes by conducting qualitative analysis of the transcripts, including the constant comparison method (e.g., Glaser & Strauss, 1967). Themes were identified by looking for recurring ideas, metaphors and analogies, and categories or classification schemes offered by the interviewees. The interview data were then sorted according to these major themes. Finally, metacoding was done, analyzing units of transcript data to examine the prevalence of themes and the relationships between the original research questions and the emergent themes (Ryan & Bernard, 2003).

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[6] http://www.ohs.org.uk/journal/
[7] http://www.afsnet.org/publications/jaf.cfm

Results

In analyzing the interview data, findings emerged regarding three major elements of the process of becoming an interdisciplinary researcher: 1) the points of entry to this type of work and to the interdisciplinary space where this work takes place; 2) what facilitates people's continued work in and navigation through this space; and 3) strategies for successful interdisciplinarity. In the participants' discussions of each of these elements, the theme of community emerged repeatedly, suggesting that this is a significant theme across the pathway to interdisciplinarity, meriting further examination. Another common theme across the participants' stories was what we call "intentional serendipity," referring to the scholars' tendencies to talk about steps in their pathways in terms of luck or chance, while at the same time providing evidence of intentionality in making those steps happen. These two themes are used here as lenses for examining and interpreting pathways to interdisciplinarity, and will help further our understanding of how to support scholars on such pathways.

As we explore the role and nature of community in relation to the above pathway elements, excerpts from selected participants' stories will be shared[8]. The stories told below are representative of our data set, and were intentionally chosen to illustrate the experiences of scholars at different points along the pathway: a scholar who is relatively new to the field (Jeff), one who has an intermediate amount of experience with this work (Kathryn), and one who has significant experience and is a long-standing member of the engineering education community (Diane).

How Do I Begin? Entry Points to Interdisciplinary Research

Jeff: As a doctoral candidate in a traditional engineering department, Jeff is still in the early stages of his career path. However, he is already aware of his need to align his research path with his passion for teaching. Early in his doctoral program, he taught several classes as a TA. He became intrigued with teaching, and began his own informal search for journal articles about teaching. He eventually realized that "my interest in teaching and learning was strong enough that I wasn't sure I wanted to continue in the program, because I thought I might want to just start teaching. And I guess the notion of doing more research to complete the Ph.D., kind of postponing my interest in teaching…I wasn't sure if I would be happy doing that." Fortunately, around the time he completed his master's degree, "things started to shift around" in his department, and he found a group of fellow graduate students who were also very interested in teaching. At the same time, Jeff's advisor made "a pretty big shift" in his career, steering his research in an educational direction. The combination of a likeminded advisor and a supportive group of colleagues "set the stage to make it feel like it was feasible" to do an education-related thesis within this traditional engineering department. Jeff then embarked on an engineering education research study for his dissertation. Since beginning this educational research, Jeff has ventured further into the engineering education community, attending conferences and meeting others in the field. As a result, he has already connected with several people from around the country doing similar work – a supportive network whose importance he clearly recognizes: "I don't think I'd still be working on this topic – I think I would have given up, actually, if it weren't for these people." Reflecting on his pathway so far into the field of educational research,

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[8] All names of study participants are pseudonyms.

Jeff observed that "to some extent my choice of fields has been directed by the people that I happen to meet who happen to have the time to help me." However, he also noted that "I've learned by now that you don't just run into people, that you try your best to run into certain people."

Kathryn: Since high school, Kathryn has always sought a sort of middle path, preferring to "sit in the middle" rather than pursue a single discipline. Looking back at her education and career path, she observed, "There hasn't been a time in my life that I've ever been solidly in an institutional discipline situation. So, yeah, I've kind of been interdisciplinary forever." Kathryn reflected on the pathway that brought her to her current faculty position, where engineering education is her primary research area. Coming from a field that is a hybrid of science and engineering, Kathryn was already on the edge of a traditional discipline. However, moving into engineering education was, she felt, an even bigger leap beyond the boundaries of the disciplines she knew. She described her first introduction to engineering education as "an accident" during graduate school, having seen by chance a flyer for a student chapter of the American Society for Engineering Education (ASEE) on her campus. She became involved with that group, which provided "a kind of an anchor" for her, and she began attending ASEE events. However, she marks the beginning of her real involvement in engineering education at a later point, after becoming a faculty member. Again, as if by accident, she was "pulled into a grant" with colleagues in math education. "I had no idea what was going to happen, I was just told 'do this.'" In fact, she described the grant's very existence as "completely luck," attributing the collaboration of engineering and education faculty to very coincidental circumstances. Kathryn credited this "lucky" collaboration with bringing her into educational research, stating, "I would not have learned how to get into this at all if I hadn't been on that grant." Her colleagues on that grant were "good mentors" as she learned to do educational research, which enabled her to be brought into subsequent engineering education research projects as "the education expert," despite the fact that she felt that she was "on shaky ground," still being new to the field. Still walking a middle path, Kathryn began to be seen – and to see herself – as an educational researcher.

Diane: "This is it," thought Diane when she first saw the concept map made by a fellow seminar participant. A self-described "seminar junkie," Diane has frequently explored new ways of thinking by attending seminars on various topics. This exploration has given her opportunities to come across things she "had never seen before," like the concept map. "Something clicked," and she felt that this new idea might be able to help her answer the questions that had been "hanging in [her] head" about the struggling university students for whom she was an academic advisor. Intrigued by this new way of thinking, she said to the concept map creator and his colleague, "'I'm going to convince you I should be your research partner.' So they let me be their research partner." Coming from a science background (and feeling strongly that science was not the right path for her), education was still a relatively new field to Diane. However, working with her new colleagues provided a good foundation in teaching and learning issues. A few years later, when another acquaintance came to her and offered her a job doing faculty development, she readily said "yes" and moved further into the world of education, eventually going on to pursue a doctorate in educational psychology. After completing her degree, Diane found a position in a student support services program, which happened to be at an engineering-focused university. At this university she found a group of people who were doing engineering education research,

and "just kind of naturally started to go to the events" offered by the center with which these researchers were affiliated. She got more and more involved in this community, and helped steer the center more explicitly toward engineering education research. "By a miracle," she said, Diane was eventually offered a full-time position running the center, and her career as an engineering education researcher has continued to progress from that point. Reflecting on the evolution of her involvement in engineering education research, Diane emphasized the importance of finding a group of people already working in the field. She observed that they "really welcomed me into their research, and I got to ride on their coattails a bit." She went on to say, "I don't think I would have gotten into this without them. Or…if I look now at the research I'm able to do now, it was because of them."

Every story has a beginning, and scholars' stories about their career paths often begin with tales about how they first entered their current field. These entry points may take the form of specific events, interactions with certain people, or a series of seemingly random choices or circumstances that, in retrospect, become recognized as the first steps on an important path. Although such entry points exist for any field or community, we argue that entering an interdisciplinary field, such as engineering education research, requires more facilitation than entering traditional disciplines. Pathways to traditional disciplines tend to have well known and understood entry procedures, and entrants are typically made aware of and guided through these entry points starting in graduate school. As discussed above, interdisciplinary research takes place in spaces between traditional disciplines, and the well-worn paths into the traditional disciplines do not lead into the in-between spaces. In fact, significant barriers may exist that prevent people from entering such a field. Therefore, it takes an extra push or pull in order for a scholar to cross a disciplinary boundary and step into the interdisciplinary space. Those pushes and/or pulls are often easily recognized in retrospect, if not at the time they first occur, and figured prominently in each of the stories told to us by our study participants. As illustrated in the story excerpts above, our study findings suggest that entry points to engineering education research are intersections of interdisciplinary tendencies, persistent questions about teaching and learning, and a catalyst, such as an event, influential person, or contact with a certain group. This combination of factors makes entry possible, and also acts as a propellant to move the person through the entry point.

As our study participants told their stories, their self-descriptions revealed some interesting commonalities, including a certain point of view or disposition: a tendency to draw from multiple perspectives and to be open to ideas outside of one bounded discipline – what might be seen as interdisciplinarity (Klein, 1990, 1996). For example, Kathryn described herself as following a "middle path," while other scholars talked about always being drawn to "hybrid" disciplines or being "bored if I were doing just one thing." One participant jokingly described herself as a "Jill of all trades, master of none." Several of our participants took their varied interests a step further, and earned degrees from multiple disciplines. Even those scholars who had followed fairly traditional paths for most of their careers referred to habitual exploration of new ideas, such as regular reading of literature outside of their discipline, attending seminars on a wide range of topics, or general intellectual curiosity.

Also common in the participants' stories were persistent or "nagging" questions about teaching and learning, as seen above in Diane's story. When asked about how they began doing

engineering education research, the scholars frequently reached back into their early careers and recalled questions that arose and would not go away. Some study participants recalled specific questions, such as "Are certain ways of studying more efficient than others?" or "Why are my students learning this, and not learning that?" Others reported more general feelings of dissatisfaction with what they saw happening in the classroom, thinking, "There has to be a better way to do this," or "Something's missing, I just don't know what."

However, simply having these nagging questions, even combined with a willingness to look across disciplines for answers, was not enough to bring these scholars into the world of engineering education research. In each case, a catalyst was required in order to create an entry point and to propel the person through it. These catalysts could be influential individuals, events, or encounters with certain groups of people. Participants often credited friends or colleagues in education disciplines with pulling them into the world of educational research. For example, one participant recounted how she was spurred into taking her first steps over the boundary by a friend who was then a student in the college of education. Aware of the participant's questions about teaching, this friend told her, "'You need to go over and talk to some people I know [in the college of education].' … She *dragged* me over there, literally." Another participant cited as significant his discovery of a group of people whose work provided answers to his nagging questions. "I somehow – kind of hooked up, found, lord knows how, a small community" doing psychology research in the context of his engineering field. He recalled that, "my jaw dropped. I thought, 'This is it! I have to do this in education.'" As the participants' narratives about these pivotal events unfolded, they often used terms like "aha moment," "revelation," or "epiphany," underlining the significance of these catalysts as entry points for the scholars' pathways.

In regard to the role of community in finding entry points to interdisciplinary research, our findings suggest that it is not simply community in general, but a particular type of community that is critical. As discussed above, the catalyst necessary for pushing or pulling a scholar over the boundary and into the world of education is often an individual or small group, frequently locally-based. These small, local communities are significant because they are perceived as accessible entry points, with perhaps a lower entry threshold than a large and/or national community. If a scholar is "pulled" into an education-related grant by colleagues, as in Kathryn's case, or is guided toward educational literature, theories, or methods by respected friends, taking that first step may seem more possible than if a scholar were left to her own devices. Larger communities, despite having the seeming advantage of being well-established and validated, may appear to have high boundaries and strict definitions of membership, which can make entry seem less feasible (or appealing) to newcomers. Once a scholar has entered a community of practice, the person's relationship to that community is that of a newcomer, engaging in what Lave and Wenger (1991) call "legitimate peripheral participation" – joining and acting in the community in accepted, appropriate ways, yet still acquiring the knowledge and skills needed for full participation.

Working in and Navigating through an Interdisciplinary Space

Jeff: Jeff realizes that by placing himself in the world of engineering education research, he is outside the boundary of his home discipline. As he put it, his work "doesn't fit into any – not

even a fringe area" of his engineering field. Reflecting on what has made it possible for him to continue working in this field, Jeff cited connections with people more than any other factors. Connecting with both local and national communities of engineering education researchers has been crucial to Jeff's continuing with this type of research. Regarding on the importance of his local community, he explained that a graduate research position at an engineering center for teaching and learning turned out to be valuable far beyond the one-year tenure of that position because of the people he met, the networking he did within the community, and the structure that allowed him to focus on educational research.   Jeff went on to say, "Why that worked isn't just the structure. I think the community is there, too, the fact that I had people that were interested in the work, who were interested in similar things, opportunities to kind of trade expertise, but also feedback and all these other things." He is still very involved with the community of researchers at the teaching and learning center, and finds this connection valuable: "People will understand what I'm working on, even if they don't have a close connection with it." Moving beyond the local community to the national community, Jeff talked about his efforts to attend national engineering education conferences, such as the Frontiers in Education (FIE) and the American Society for Engineering Education (ASEE) meetings, and commented on "how great the community is" at these venues. He went on to say, "I feel very comfortable [at these conferences]. I feel like I can just think and talk about my perspective on research and teaching in [his engineering discipline] without hesitation." FIE "feels like home and not just in these kind of intellectual ways, because of the size, because of how it's structured, and the people who go there, I really feel it's a very, very special place." At these conferences he has been able to forge connections with other members of the national community by presenting papers and posters, which provide "a great vehicle for getting a conversation started." These conversations have the potential to lead to further connections, such as the time he met a group of people from another university via his poster, and "By the end of the conference we were arranging for me to visit for a few weeks and kind of help out as one of their observers in an evaluation that they had been tasked to do. So it was totally amazing." Talking about meeting these researchers and actually getting involved in their work, Jeff said, "They have been tremendously encouraging ever since that time, so little things like that have made a huge difference." Looking at where he is now, Jeff reflected that, "I have finally gotten to the point where I really do feel like…I might actually have something worthwhile to offer" to others who want to enter this community and do this type of work.

Kathryn: For Kathryn, her story of navigating the field of engineering education research is also a story about the evolution of local and national communities of which she has become a part. Regarding her local colleagues, she stated that, "The research group I've been in, it wasn't just me going through the growing pains, it was a number of people trying to understand the different language." At the national level, she perceives a growing receptiveness to education research within the broader engineering community, which has made it easier in many ways for her to continue with this type of work. "It's been a big shift," she observed, noting that with the growth of grants for large technical research centers, engineering faculty now "realize they have to have this education component, and they're starting to come out of the woodwork to try to figure out what it is we do." However, she recognized that her perceptions may be colored by the circles within which she moves, which may be more receptive to this work than the engineering community at large. She commented that, "I have a sheltered life. I don't go too far…out of range of people who at least have an inkling, I think" about education research. With some

engineering education research experience under her belt, Kathryn is now in a position to observe others' efforts to enter this research community. "Now I sit in that kind of middle road," she said, "talking to my engineering colleagues and kind of seeing them faced with the same kind of newness that I had to go through." Reflecting on her background in a "hybrid" science and engineering field, she noted that her field "had no home," without a conference or journal of its own (until recently). Kathryn's current work in engineering education research also places her in a field that is between disciplines. However, unlike Kathryn's former field, this particular interdisciplinary space seems to be functioning as a "home," by providing not only conferences and publication venues, but also a growing community of similarly "homeless" researchers. As for her next steps, Kathryn reflected, "I have a long history of falling into things backwards, and it's OK. Here I am." "I don't really know where I want to go next. I'll kind of wait and see what happens, where I fall into it again, I don't know."

Diane: Connections to various people and groups have been the key to Diane's increased involvement in engineering education research. Talking again about the group of likeminded colleagues at her current (at the time of the interview) university, she reiterated how she benefited from their experience, and emphasized that "they're still folks that I do a lot of research with." In addition to maintaining connections with this community, Diane has also worked to bring other colleagues into their research, casting her net wider to other universities and disciplines. For example, the group's current research involves a collaborator from another university who is a well-known education researcher. Diane was able to meet this researcher at a conference several years earlier, and developed a working relationship which continues today. The development of what seemed like a fortunate and coincidental interaction into a lasting collaboration still amazes Diane. "There are times," said Diane, "I still cannot believe that she works with us." Talking about their current project, "Really our research is her research. And it's just so unreal." As she makes these connections, Diane sees herself as "the bridge." She stated that she doesn't have the content expertise of either the engineering faculty or the education experts, "But what I've been able to do is go in and bring both sides together." From her perspective, to make this kind of interdisciplinary research work, "You need a bridge. My thought is that you probably need somebody that can kind of understand each a little bit." Beyond the evolution of her local community, Diane also talked about the importance of national communities, such as those she finds at conferences, and the various roles of these communities in her professional life. For example, she regularly attends the annual ASEE (American Society for Engineering Education) meetings, and felt that "in many ways it's my community, but it's not my intellectual community." She is also a regular participant at the AERA (American Educational Research Association) conference, which she described as her "intellectual home." She went on to note that AERA's Division I has been a significant community for her, since "they have been tremendously welcoming to me…I feel that our work is welcomed there, it's valued there."

After taking the first few steps and finding entry points to the engineering education community, our study participants all found ways to remain in this field. As illustrated in the discussion of entry points, a small, local community can be an important catalyst for moving into an interdisciplinary field. Similarly, once a scholar has cleared the initial hurdles and entered the field, being part of a supportive community is often what makes it possible to continue working in and navigating through this interdisciplinary space. However, the nature of that community

and a scholar's relationship to it are likely to change as the scholar's work progresses. Our findings showed that, although each study participant began their story of interdisciplinary research with a connection to a small and/or local community, none of them stopped there. All of the scholars went on to expand the definition of their community, broadening the boundaries of what they considered to be their "home" group, and making connections to more people and groups at further distances – in terms of geography, background, or experience. Rather than leaving behind their original communities, those initial connections became subgroups within the larger circle of their new "home" community. This expansion from one's initial community outward, creating larger and larger concentric circles of community, may be a natural progression for anyone entering a new field. However, we argue that expanding networks and increasing one's level of participation in a community of practice is particularly important in an interdisciplinary field such as engineering education research, where these connections may be the only support a scholar has in doing what may be seen as unconventional (and sometimes unrecognized) work by traditional disciplines.

As the scholars' communities expanded their positions in and relationships to these communities also evolved. As discussed above, when the scholars initially entered the field of engineering education research, they engaged with the existing community of practice in an apprentice-like way (Lave & Wenger, 1991). Through the process of legitimate peripheral participation (Lave & Wenger, 1991), the scholars continued to learn more about engineering education research, became more active participants in the community, and became increasingly fluent in the community's social practices. As the scholars' participation in the community of practice grew, they also tended to identify with that community to a greater degree. Although many study participants retained a significant identification with their traditional engineering disciplines, they all referred to their educational research in some way in their self-descriptions, and some even stated "educational researcher" as their primary professional identification. Another indicator of identification with the engineering education research community was the scholars' discussions of the professional groups that felt most like "home" to them. Virtually every participant reported that they felt most comfortable in or connected to (or "recharge batteries" at) engineering education contexts such as the American Society for Engineering Education (ASEE) or Frontiers in Education (FIE) conferences. Some went on to note that they no longer went to conferences for their traditional engineering fields. As Lave and Wenger (1991) observe, "identity, knowing, and social membership entail one another"(p. 53). Our participants' stories seem to illustrate this point well, demonstrating that their membership and participation in the engineering education research community, their knowledge about this field, and their identification as engineering education researchers evolved in interconnected ways.

Managing the Boundary: Strategies for Interdisciplinarity

Jeff: Jeff is very aware of his position at the boundary between his engineering discipline and education, and recognizes that succeeding in this boundary region takes some effort. However, this is an effort he does not mind making, since it makes it possible to do the work he enjoys. "You have to find somewhere to fit in" he observed. "More likely you'll have to deal with the fact that you don't fit in. I'm very lucky here, actually. You'll have really serious problems and obstacles to deal with that nobody else in your department would even consider, and I think you

have to be honest with yourself and give yourself the time to deal with those things. … That was actually quite scary. But I'm glad I did it." He went on to comment that, "If I had conventional career ambitions, what I'm doing is suicide. … But that's OK for me." In order to make this boundary position work, Jeff has been very intentional about things like "spinning" his work for different audiences, presenting it differently on each side of the boundary – that is, for traditional engineering audiences and for education researchers. He gave the example of one of his student colleagues who "spun" his work in this way for his job hunt, creating "two different sets of faculty application materials, two different job titles," depending on the type of institution to which he was applying. "It's the same work, but very – completely different angles, different observations." In addition to the challenge of presenting his work in the right way, Jeff also talked about other challenges he has had in this boundary position. For example, as a new researcher, he has had trouble finding the information he needed about "navigating the culture of academia, of managing, advising your relationships, on the challenges, striking out in new directions, some interdisciplinary work…It's relatively underdiscussed. … I want people to understand realistically that it's very, very challenging to do this, especially as a grad student." Despite these challenges, Jeff has made this pathway work so far, and is now in a position to offer advice to others. For example, "One of the most important things that I've learned is I have to continue to push myself to talk about my work, have to toss it out there. And when people ask what I work on, be ready with a really good, snappy response, take advantage of as many of those opportunities as I can…. That's number one."

Kathryn: Kathryn is now in a position to look back on her pathway into engineering education research and see how she overcame certain challenges associated with working in this interdisciplinary space. "I came through the route that I see every one of my colleagues struggling with," she said. She observed that for many engineers entering educational research, "You come in, you're a quantitative person, you want to have control groups, and you can't understand what this qualitative junk is all about." In addition to the general challenge of getting used to doing qualitative research, she cited the difficulty of accessing literature on educational theory and methods: "To me it's still kind of a hodgepodge how people figure it out. It would just be nice if there was a solid resource data bank kind of thing for people." Kathryn also talked about the difficulty of balancing traditional engineering research with educational research, and has found it to be more practical to place herself fairly firmly on the educational research side of the boundary. She noted that, "it's a hard climb, and you have to give up things – if you're really going to do it, I think you've got to give up some of your technical research, not all of it…I don't see how anyone can do both." Fortunately, giving up some of her traditional engineering work (and identity) in favor of engineering education research seems to have become a more viable option in recent years. With the growth in size and visibility of the national engineering education research community, "now you can say, I'm an engineering education researcher…and then you can point to, yes, and these other people are, too." The importance of being part of a larger community also came up when Kathryn reflected on what might help other engineers start doing educational research. She cited some of the intensive workshops that have been offered on engineering education research, which work to create "these communities where they're trying to train people differently" as being "a huge help. I wish I had those kinds of opportunities at the time [when she began doing this type of work]. I think that eases the growing pains some."

Diane: "I'm the bridge," said Diane, when talking about her position in the interdisciplinary space between engineering and education. She recognizes that she may not always have the degree of expertise that her colleagues do in their respective disciplines, "But what I've been able to do is go in and bring both sides together." She sees this role as a common one in interdisciplinary work, observing that, "You need a bridge. My thought is you probably need somebody that can kind of understand each a little bit." She went on to say, in regard to interdisciplinary work, "it should be this meshing of, not just two fields side by side, but one field really informs another field. And almost by definition, that takes collaboration, because almost no one really has enough expertise in either field. And I think it also takes people who are willing to be boundary crossers." Being this sort of bridge or boundary crosser is not always easy, though, and Diane cited several challenges that she has come across, such as figuring out where to publish her work, and continuing to pursue the direction that felt right to her, regardless of the perceptions of others. Offering advice to others who may wish to embark on an interdisciplinary pathway, Diane quoted Joseph Campbell: "He said, 'Follow your bliss and don't be afraid, and doors you never knew were there will open for you.' And the 'don't be afraid' is the…key part of that." From her own experience, she recalled that, "Just having somebody say, 'You know, you've got to follow your heart,' seem[ed] to be very reassuring." Expanding on the value of support from others in following this pathway, Diane went on to talk about the importance of mentors and social networks in helping people enter and continue working in interdisciplinary spaces: "Mentoring is so crucial, if there are ways that we can help them find mentors, or introduce them to people, or help them make those first few scary steps a little more known, I think that's also a threshold sometimes." Despite the challenges, Diane strongly encouraged others who might be interested in entering engineering education research – or any new field – to follow her example: "If you have a question, if something seems like you should go in that direction, just not to question it. Just do it."

Our study participants were all very conscious of their positions in an interdisciplinary space and the need to "manage the boundary" between this space and their home disciplines. As such, they were able to articulate the challenges they had faced as well as strategies they had used or would recommend for managing such positions. Certain challenges were mentioned by several of the interviewees, pointing to the difficulties of moving into a new field, particularly when that field is outside of traditional disciplinary boundaries. For example, the scholars talked about the risks involved in stepping outside of their home disciplines, and also about the difficulty of entering a new community of practice. By working in an interdisciplinary area, some scholars experienced a lack of collegial support in their home departments. Scholars were also faced with questions of where to publish their work and how to make this work "count" in terms of tenure and promotion. As they began to draw from the field of education, they found that new terminology had to be learned, new literature had to be navigated, and new approaches to research methods and evidence had to be learned and accepted. In other words, the scholars had to gain fluency in the "Discourse" of the new community (Gee, 1989).

Despite the challenges described, all of our study participants had found ways to continue doing engineering education research, and seemed to be successfully managing interdisciplinary positions. When asked about their strategies for this success, the scholars told their own stories of overcoming challenges and also offered suggestions for other who might wish to enter

engineering education research or other similar interdisciplinary fields. As seen in the three stories featured above, strategies included things like presenting one's work differently depending on one's context, making an effort to seek out likeminded people and communities, and pursuing interesting directions even if the path seems difficult. Other participants also echoed these strategies, encouraging newcomers to get involved in national conferences, read broadly, network and connect with the broader engineering education community, and in general "be confident in yourself" and "just do it."

Again, the theme of community emerged, running throughout the scholars' discussions of managing the boundary and strategies for success. Some type of community connection was cited by virtually every interviewee as a crucial strategy. This element of the interdisciplinary pathway is not really a chronological step, but is rather something that was woven throughout our participants' stories, with perhaps greater emphasis at the end of our conversations when they were specifically asked about their strategies. As such, our findings about community in regard to "managing the boundary" are not about an ending point for the scholars' journeys, nor do they tell us about the ultimate nature of interdisciplinary scholars' participation in communities of practice. Rather, the significant finding here is the fact that references to community were so prevalent in each scholar's own strategies and their suggestions for others. This prevalence, combined with the scholars' insistence on the great importance of community connections and support, made it impossible to ignore this theme in the data. The idea that communities of practice are important is not new; however, our findings provide further evidence to support this commonly held notion. As such, we assert that significant efforts need to be made to build and support communities of practice, not only in engineering education research, but in other interdisciplinary areas as well.

Discussion

This exploratory study set out to examine what it means to be a scholar in an interdisciplinary area, and to illuminate the process of becoming an interdisciplinary scholar. Our findings suggest that there is no single correct entry point or pathway into interdisciplinary work. However, scholars' pathways do share many commonalities, and understanding these commonalities will help us better support those who are on these paths. One observation that emerged from our findings is that interdisciplinary work cannot easily be done in isolation. Community is, of course, important in any field or type of work, but it appears to be particularly critical when entering and working in an interdisciplinary field. Moreover, it is not just community in general that is so important, but certain types of community which come into play in different parts of the pathway. Although the theme of community ran throughout our participants' stories, the nature of the community in question and the narrators' relationships to it varied in significant ways, depending upon which element of the pathway was under discussion. Our findings highlight the need for the notion of "community" itself to be unpacked, which we have started to do in this paper, and hope to explore further in future work.

As discussed above, as the nature or boundaries of the scholars' communities evolved, so did their relationships to those communities, as evidenced in their statements about their professional identities. Following Lave and Wenger's (1991) notion of legitimate peripheral participation, as the scholars' participation and fluency in the new community of practice grew, they also began

to identify with that community. The nature of this identification emerged in the scholars' stories, both explicitly in statements about how they identified or what they called themselves, and implicitly in descriptions of their work and how they positioned themselves in relation to the fields of engineering and education. Each scholar had a slightly different way of describing his or her identity and position in the interdisciplinary space between engineering and education. However, these responses had in common an intentional inclusion of both the engineering and education sides of their professional lives. The scholars' initial responses were succinct, along the lines of "educational researcher," "engineering educator," or "professor of" a certain engineering discipline "with an educational research focus." They then went on to expand upon or clarify these labels, providing more insight into what these identities meant to them. For example, some scholars highlighted the interdisciplinary nature of their identities, calling themselves "bridges" or "translators." The scholars' ways of talking about themselves acknowledged that the community which they have entered is inherently an "in between" space.

"Intentional Serendipity"
As we step back from the stories, we see an interesting theme emerging – a tendency to frame many of the steps along their pathways in terms of luck or chance. This was particularly evident regarding social interactions within local and more global communities. For example, entry points were often talked about as events or connections that were stumbled upon, happened by sheer coincidence, or were caused by forces beyond the participants' control. Participants "just happened" or were "lucky" to know or meet people who could guide them into educational theory and methods. Opportunities to get involved in education research projects seemed to "just come up" or were "assigned," or scholars were "luckily" offered education-related positions. As one participant put it, "I felt really lucky that I just stumbled into this [educational research] by accident." As the scholars described moving further along their pathways and becoming more involved in engineering educational research, the language of "luck" continued to have an important presence. They continued to meet other likeminded researchers by chance, stumbled upon other communities, and were "luckily" asked to be involved in further educational research projects. Even looking over the full length of their pathways in retrospect, some participants framed their experiences as a series of odd events, as in, "My trajectory has been so bizarre."

Despite this language of "luck," the intentionality of their actions is apparent in the scholars' efforts to meet people who can provide entry, build community networks, and construct an identity as an interdisciplinary engineering education researcher with others in the community. Although some of the described occurrences certainly have a serendipitous or coincidental quality, such coincidences were part of virtually every participant's story, calling into question the reasons behind the prevalence of such luck. One way of interpreting this prevalence is what we call "intentional serendipity." By this term we intend to highlight the way that critical events and connections are framed as happening merely by chance or luck, even though the scholars' stories clearly show that they intentionally positioned themselves in certain ways or took actions that made it possible for these "lucky" things to occur. This intentionality took various forms, such as applying for certain jobs, introducing themselves to key people, attending certain conferences, or simply making a point of being open to new ideas from outside their home disciplines. For example, one scholar recalled that shortly after a new opportunity in education "came up" (one in a series of "lucky" opportunities), she intentionally went out and "pressed the flesh, I cold called, I visited…. So everybody knew me." Other scholars stated how "fortunate"

they were to be working in environments where engineering education research was possible and respected (or at least "tolerated," sometimes "with benign neglect"), downplaying the deliberate efforts they had made to seek and gain positions in such environments. A certain amount of this "luck" language may be attributable to our study participants' modesty about their roles in their accomplishments. However, what was striking in analyzing the interview data was the frequency of the serendipitous framing of events, coinciding with evidence of intentionality in the scholars' pathways – and our sense that tales of pathways into traditional disciplines might be framed in much more intentional and less serendipitous ways.

Implications

By better understanding interdisciplinary work, we can make visible interdisciplinary ways of thinking and the process of constructing interdisciplinary identities. This knowledge can then be used to design environments for bringing people into interdisciplinary scholarship and scaling up programs that build capacity and sustain communities. This research will be used to support those who work in interdisciplinary spaces, and explore how programs that work to build capacity in engineering education research can be effective "change pathways" for improving engineering teaching and learning.

Our study findings also have implications for other interdisciplinary fields, particularly those connecting education and science disciplines or professional fields, such as medical education. In each of these fields, researchers must step outside the borders of their home disciplines and traditions of technical research, draw from the field of education, and redirect their gaze toward the teaching and learning going on in their classrooms. This sort of pathway is not as familiar, prescribed, or understood as the routes into and within traditional disciplines. Therefore, the nature of interdisciplinary pathways must be made explicit, and individuals along such paths must be supported by the relevant community of practice to a greater degree than is needed in traditional disciplines. When taken in conjunction with the Carnegie Initiative on the Doctorate and the Woodrow Wilson study on Re-envisioning the PhD, this study may also provide insights into models for effectively preparing people for all forms of professional practice (disciplinary as well as interdisciplinary). We anticipate that those involved in other interdisciplinary fields will resonate with our scholars' stories, and can apply the lessons learned here in supporting colleagues who are embarking on similar interdisciplinary work.

References
Barley, S.J. (2001). Puddle jumping as a career strategy. Unpublished document. Stanford University: Center for Work, Technology and Organization, Department of Management Science and Engineering.
Barretti, M. (2004). What do we know about the professional socialization of our students? *Journal of Social Work Education,* 40(2), 255-283.
Bromme, R. (2000). Beyond one's own perspective: The psychology of cognitive interdisciplinarity. In P. Weingart and N. Stehr (Eds), *Practising Interdisciplinary,* pp. 115-133. Toronto: University of Toronto Press.
Bruner, J. (1986). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.
Bruner, Jerome. 1991. The Narrative Construction of Reality. *Critical Inquiry,* 18, 1-21.

Bruner, J.T. (1992). *Acts of Meaning: Four Lectures on Mind and Culture (Jerusalem-Harvard Lectures)*. Cambridge: Harvard University Press.

Bruner, J. (2002). *Making stories*. New York.

Butler, S., and Bentley, R. (1996). *Lifewriting: Learning through personal narratives*. Scarborough, Ontario: Pippin Publishing, 1996.

Committee on Facilitating Interdisciplinary Research (CFIR), Committee on Science, Engineering, and Public Policy (2005). *Facilitating Interdisciplinary Research*. Washington, DC: National Academies Press.

Cook, T.H., Gilmer, M.J., & Bess, C. (2003). Beginning students' definitions of nursing: An inductive framework of professional identity. *Journal of Nursing Education,* 42(7), 311-317.

Edelson, D.C. (2002). Design Research: What we learn when we engage in design. *The Journal of the Learning Sciences*, 11(1), 105-121.

Egan, K. (1995). Narrative and learning: A voyage of implications (pp 116-125). In H. McEwan & K. Egan (Eds). *Narrative in teaching, learning, and research.* NY: Teachers College Press.

Egan, K. (1999). *Children's minds: Talking rabbits and clockwork oranges.* NY: Teachers College Press.

Erickson, K.C. (2003). "'They will come from the other side of the sea': Prophecy, ethnogenesis, and agency in Yaqui narrative." *Journal of American Folklore,* 116(462), 465-482.

Frost, S.H. & Jean, P.M. (2003). Bridging the disciplines: Interdisciplinary discourse and faculty scholarship. *The Journal of Higher Education,* 74(2), 119-149.

Galison, P. (1997). *Image and Logic.* The University of Chicago Press: Chicago.

Gee, J.P. (1989). Literacy, discourse, and linguistics: Introduction. *Journal of Education,* 171(1), 5-17.

Gee, J.P. (2001). Identity as an analytic lens for research in education. *Review of Research in Education,* 25(200-2001), 99-125.

Gidjunis, J. (2004). Interdisciplinary research urged. *The Chronicle of Higher Education*, 51(15), A25.

Glaser, B.G. & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research.* New York: Aldine.

Gomez, M.L., Stone, J.C., & Hobbel, N. (2004). Textual tactics of identification. *Anthropology and Education Quarterly,* 35(4), 391-410.

Karpiak, I (2000). "Writing Our Life: Adult Learning and Teaching through Autobiography." *Canadian Journal of University Continuing Education* 26(1), 31-50.

Klein, J.T. (1990). *Interdisciplinarity: History, theory, and practice.* Detroit: Wayne State University.

Klein, J.T. (1996). *Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities.* Charlottesville, VA: University Press of Virginia.

Lattuca, L. (2001). *Creating interdisciplinarity: Interdisciplinary research and teaching among college and university faculty.* Nashville: Vanderbilt University Press.

Lauzon, A.C. (1999). Situating cognition and crossing borders: Resisting the hegemony of mediated education. *British Journal of Educational Technology,* 30(3), 261-276.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* New York: Cambridge University Press.

McCabe, A. (1997). Cultural background and storytelling: A review and implications for schooling. *The Elementary School Journal,* 97(5), 453-473.

Paley, V.G. (1990). *The boy who would be a helicopter: The uses of storytelling in the classroom.* Cambridge, MA: Harvard University Press.

Personal Narratives Group (1989). Origins. In Personal Narratives Group (Eds.), *Interpreting women's lives: Feminist theory and personal narratives.* Bloomington: Indiana University Press.

Pfirman, S.L., Collins, J.P., Lowes, S., and Michaels, A.F. (2005). Collaborative efforts: Promoting interdisciplinary scholars. *The Chronicle of Higher Education,* 51(23), B15.

Riordan, T. & J. Roth (Eds) (2005). *Disciplines as Frameworks for Student Learning: Teaching the Practice of the Disciplines.* Sterling, VA: Stylus.

Ryan, G.W. & Bernard, H.R. (2003). Techniques to identify themes. *Field Methods,* 15(1), 85-109.

Sanjek, R. (1990). On ethnographic validity. In R. Sanjek (Ed.), *Fieldnotes: The makings of anthropology.* Ithaca: Cornell University Press.

Sfard, A. & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher,* 34(4), 14-22.

Spanner, D. (2001). Border crossings: Understanding the cultural and informational dilemmas of interdisciplinary scholars. *The Journal of Academic Librarianship,* 27(5), 352-360.

Spradley, J. (1979). *The ethnographic interview.* New York: Holt, Rinehart and Winston.

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., Unger, J., Palmer, P., Clark, M.A., Colby, S.M., Morgan, G., & Trochim, W. (1998). Evaluating transdisciplinary science. *Nicotine & Tobacco Research,* 5(1), S21-S39.

Thames, D.G. & York, K.C. (2003). Disciplinary border crossing: Adopting a broader, richer view of literacy. *The Reading Teacher,* 56(7), 602-610.

Turns, J. (2006). *Narratives supporting excellent teaching (NEXT).* http://depts.washington.edu/next/index.php

Young, L.J. (2001). Border crossings and other journeys: Re-envisioning the doctoral preparation of education researchers. *Educational Researcher,* 30(5), 3-5.

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