



Building Research Capabilities at the Intersection of Engineering Education, Systems Engineering, and Writing Studies

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ABSTRACT

CONTEXT

Since Borrego et al. first analysed collaborations between engineering faculty and social science researchers, engineering education doctoral programs have grown globally to build research capabilities. But even with these doctoral programs, engineering faculty continue to transition from technical to educational research through collaboration. Yet little recent work has examined how these collaborations contribute to engineering education capabilities.

PURPOSE OR GOAL

To explore the impacts of interdisciplinary collaboration on engineering education research capacity, this practice paper reports on an ongoing collaboration that involves researchers from systems engineering, writing studies/ rhetoric, and engineering education. Funded by the U.S. National Science Foundation under a program designed to build EER capacity, the collaboration centres on the ways embedded writing assignments build students' engineering identities. Using our collaboration as a case study, we examine how our exchange of theoretical frameworks, research methods, and prior literature has shaped our shared work and our identities as researchers to ask, "How does an interdisciplinary research collaboration contribute to the development of engineering education research capability?"

APPROACH OR METHODOLOGY/METHODS

We use Wenger's Communities of Practice (CoP) to capture the process of ongoing mutual engagement as we share knowledge, methods, and research interests across fields. Wenger's framework is particularly useful because it recognizes how newcomers do not simply conform to existing practices, but instead contribute to and reshape the community. Data includes meeting notes, paper drafts, and individual reflections.

ACTUAL OR ANTICIPATED OUTCOMES

Our work provides a contemporary understanding of the ways interdisciplinary collaborations expand engineering education research capabilities, not only through training new researchers but also through integrating new disciplinary perspectives that reshape the field through mutual engagement in joint enterprises. Our findings will help identify practices that support (or hinder) such collaboration.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Our experiences point to the ways in which developing research capability is not simply a one-directional process of training new researchers, but rather an ongoing dialogue that expands the capacities and identities of all collaborators. These findings echo and extend earlier work by highlighting the dialogic processes by which all collaborators build capacity. Even as the field has grown over the last decade and a half, with many new researchers coming up through engineering education doctoral programs, the field itself continues to shift and expand through interdisciplinary engagement beyond our disciplinary borders.

KEYWORDS

communities of practice, interdisciplinary collaboration

Introduction

In their 2008 study of cross-disciplinary collaborations in engineering education, Borrego and Newswander (2008) identified the dominant model as one in which engineering faculty brought the problem (including “problem statement, context, and motivation” (p. 128) while the social science researcher “provide[d] structure by applying theory and methods relevant to the problem at hand” (p. 128). Using interdisciplinarity as a conceptual framework, the study examined the ways in which collaborations between engineers and social scientists led each collaborator to expand their understandings of world views and intellectual traditions as they learn from one another, though often that learning seemed to be primarily centred on the engineers learning theory and methods and the social scientists learning context. These findings echo a previous study in which Borrego (2007) found that engineers learning education research experienced significant conceptual difficulties in terms of the openness of research questions, the use of theoretical frameworks, the inclusion of qualitative methods, and the complexity of defining and measuring key constructs.

But much has changed since 2008. Though engineering education has a history dating back decades (e.g., the *Australasian Journal of Engineering Education* began publications in the mid-1990s, the *European Journal of Engineering Education* began in 1975, and the U.S.-based *Journal of Engineering Education* is now in its second century), the early 2000s marked a significant growth in the formalization of this research into its own “internationally connected field of inquiry” (Borrego & Bernhard, 2011, p. 14). While Jesiek et al. (2009) highlighted the lack of “a shared body of knowledge, standards of convincing evidence, and terminology” (p. 47) at the first REES conference (then called ICREE – International Conference on Engineering Education Research), the growth of theories, methods, and journals in the intervening years have moved us closer to a defined discipline than a generalized community. Perhaps most notably, while Borrego and Bernhard noted that in 2011 most engineering education researchers were trained as engineers, the growth of engineering education doctoral programs has rapidly increased the number of EER scholars with PhDs in engineering education; the Engineering Education Community Resource wiki (Carberry & Yasuhara, 2021) currently lists 30 doctoral programs around the world specifically in engineering education, with many more in STEM education broadly.

While doctoral programs have proliferated in ways that have structured – and possibly narrowed – the field’s disciplinary identity, engineering faculty continue to transition into educational research, either as a complement to or a replacement for their technical research. Indeed, the U.S., the National Science Foundation’s Research Initiation in Engineering Formation program (Engineering Education and Centers Division, 2020) is designed specifically to “[enable] engineering faculty who are renowned for teaching, mentoring, or leading educational reform efforts on their campus to develop expertise in conducting engineering education research” by conducting such research under the mentorship of experienced scholars. But although the late 2000s saw several studies on such cross-disciplinary collaborations, little work has emerged since then to consider how the development of the field has reshaped these collaboration and, perhaps even more importantly, how the collaborations continue to reshape the field. To that end, in this paper we report on the ways a recent cross-disciplinary collaboration supported with funding from the U.S. National Science Foundation has built capacity in engineering education research.

Background

The Project: WRI²TES: Writing Education Initiating Identity Transformation in Engineering Students

Several years ago, the U.S. National Science Foundation launched a funding program called Research Initiation in Engineering Formation (RIEF) designed to build engineering education research capacity by pairing engineering faculty with an interest, but little or no experience, in

the field with experienced researchers (Engineering Education and Centers Division, 2020). Teams of faculty that include the emerging researcher as Principal Investigator (PI) and at least one experienced educational researcher are invited to submit proposal for two-year projects; the proposals must include not only a description of the proposed research, but a detailed explanation of the mentoring plan through which the PI would learn key practices in engineering education research (e.g. research design, data collection, data analysis) and be introduced into the community (e.g. through conference attendance and manuscript publication). The expectations for the proposal suggest that the project is envisioned through a one-way transmission model: new researchers will be brought into the field by learning from more experienced colleagues.

In 2018, we began developing a proposal anchored in Francis' experiences of teaching writing in his advanced systems engineering courses and his previous collaborations with Riedner, who was then serving as director of the campus writing program. Paretti was invited into the project because reviews of a previous proposal submission strongly recommended adding a researcher with experience in engineering identity. The project seeks to understand how writing assignments help engineering students develop their identities as engineers, particularly in terms of enacting and justifying engineering judgement. Using artifact-based semi-structured interviews, the study employs thematic analysis to understand how students' experiences of writing throughout a project intersect with instances of engineering judgement (i.e. places in which students had to make decisions about project scope, direction, options, designs, etc. for which there was no single right answer) and their perception of themselves as engineers. The initial design of the study was grounded in Gee's (2000) framework for identity in educational research, Tonso's (2006a, 2006b) use of cultural production theory to understand identity, and Lea and Street's academic literacy approach (1998, 2006).

Our team brings together researchers from three diverse fields that all include human-subject research, though with varying methodological approaches. We share an interest in the relationship between writing and identity, but bring diverse expectations and perspectives to this issue:

- Francis was trained in civil and environmental engineering, and engineering and public policy. He primarily has experience in quantitative research through experiences in infrastructure systems risk analysis. Recently, his research has explored infrastructure and risk management using qualitative methods, in addition to the engineering education research described in this paper.
- Riedner was trained in rhetoric and composition with a focus on writing in the disciplines pedagogy. She also has an interdisciplinary background in the humanities with expertise in women's, gender, and sexuality studies. She is an interdisciplinary researcher with publications in writing studies and in feminist rhetorics. Her publications explore how public discourse and disciplinary discourse shapes student learning.
- Paretti's training includes an undergraduate engineering degree and graduate degrees in English (including work in writing studies and identity). She is a qualitative researcher who came into engineering education through research on the teaching and learning of writing in engineering. Grounded in situated learning theories, her work includes research on engineering communication in school and at work as well as on engineering identities in both contexts.

The team has been meeting biweekly for the past two years – primarily virtually since Paretti is at a different university, but we have had two in-person meetings as well (one prior to the pandemic and one in early summer 2021). Francis has also been a regular virtual participant in Paretti's research group, reading and commenting on the work of other emerging engineering education researchers as well as sharing his own work in progress. The team collectively developed an interview protocol, and Francis has conducted 11 interviews with participants. To date, the team has presented findings at two engineering education conferences, one National Science Foundation PI meeting, and writing in STEM community of practice meetings at Francis and Riedner's institution.

Conceptual Framework: Communities of Practice

To explore our collaboration systematically, we ground this discussion in Wenger's concept of learning as joining a community of practice (Wenger, 1998). In Wenger's terms, a community of practice (CoP), is not simply an group of individuals, but rather a group engaged in a *joint enterprise* characterized by *mutual engagement* and a *shared repertoire*. The joint enterprise refers to the larger set of goals, negotiated among participants, shaped by the context, and supportive of mutual accountability. For example, in an academic field, the joint enterprise is the set of concerns and questions that shape and drive the field. In a given research project, it is the overall research goal and specific questions the team seeks to address. Mutual engagement refers to the ways in which the community members interact as they pursue that enterprise, reflecting a high degree of interdependence and ongoing interaction as individuals negotiate their work together. At the field level, it includes interactions at conferences as well as ongoing dialogue through journals; in a project, it includes both the regular meetings among researchers as well as the joint productions of papers and articles for those conferences and journals. Finally, the shared repertoire refers to individual actions and practices as well as tools, concepts, stories, and language that individuals use to engage with each other. In research at both the field and project level, this repertoire includes methods of inquiry and theoretical frameworks, as well as the larger epistemological world views that guide our work both as a field and within a given project.

In this context, learning is not acquiring knowledge in one place and transferring it to another. Instead, it is a process characterized by *legitimate peripheral participation* in a community of practice (Johri, 2011; Johri et al., 2014; Newstetter & Svinicki, 2014; Wenger, 1998). That is, learning happens as new members engage in the authentic work of a given CoP, coming to understand the enterprise, interacting with other members of the community, and learning the shared repertoire. Such learning that implicitly undergirds NSF's RIEF program in the U.S.; the mentoring plans required by the program solicitation require, in fact, that the research team detail the ways in which the new researcher will be brought into the engineering education research community.

Two other facets of Wenger's framework are relevant to our exploration of capacity building. First, Wenger frames learning not simply as the acquisition of knowledge, skills, and abilities – i.e. learning to *do* engineering education research - but a matter of identity – *becoming* an engineering education researcher. Second, CoPs are not static. Instead, the nature of the enterprise, the forms of engagement, and the repertoire are continually renegotiated in practice among community members – including the new members. New researchers, that is, do not simply absorb research goals, methods, frameworks, or epistemologies from engineering education. They also bring goals, methods, and frameworks from their home fields, their prior research, their scholarly identities, and their classroom experiences. This continual renegotiation among all community members makes the process of building capacity more than simply adding new researchers to a reified field and offers ways to expand and redefine the field itself.

While recent research on capacity building in engineering education is scarce, several other scholars have drawn on CoP in this context. Following the first REES (ICREE) conference, Jesiek et al. (2009) explored participants conceptions of engineering education through the lenses of discipline, CoP, and field, with "emerging field" as the more common and neutral term. Engineering education scholars have also drawn on Wenger et al.'s ((2011) value creation framework to examine what an engineering education research initiative brings to an engineering school (Williams & Carvalho, 2011). Wenger et al. identify five types of value created. In related work, Berthoud and Gilester used the value creation framework to explore the impacts of a multi-university network focused on teaching and learning in particular technical domain. Such studies

demonstrate the ways in which the concept of value creation can be used to explore larger-scale impact of CoPs. In this practice paper, in contrast, we are interested in learning and the transformations that are occurring within our communities and within our identities as scholars and educators, and the potential implications of such transformations for capacity building in engineering education research.

Findings

This section begins with a reflection from each author describing their experiences of learning in this project, then uses CoP to synthesize the ways in which our experiences collectively have helped reshape our conceptions of engineering education research and our identities as researchers to build capacity in the field.

Francis

This collaboration with Rachel and Marie has changed my perception both of engineering education and ‘technical’ engineering research by giving me the opportunity to gain some familiarity with qualitative research design. As a scholar of infrastructure resilience, I was often frustrated by the focus on mathematical modeling of the cyber-physical systems when it seemed to me that the main factor influencing a system’s resilience was the network of human stakeholders interacting through it. This network, in my opinion, could only be effectively studied using qualitative and mixed-methods designs, and while I believe two of my PhD students successfully learned these methods, I always looked on from the outside. This collaboration—and the engineering education literature more broadly—opened my eyes to a range of research designs and methodological perspectives that seemed immensely useful in that space, including phenomenology, grounded theory, and thematic analysis.

More importantly, this collaboration has helped me to more patiently look into my own frustrations and misunderstandings when interacting with my students in the classroom. Often, the disconnects I experience with them partly arise from the ways I’ve designed my course objectives, classroom activities, assignments and projects, or a combination of all of those. Through the intentional engagement with the engineering education literature, I’ve become aware of the many avenues I could begin to seek insight into my classroom practices through this body of scholarship, while also contributing my own insights by carefully designing my own inquiry into my failures.

Finally, this collaboration has set me along a path of understanding the range of ways students come to identify with engineering through their undergraduate education. This has led me to wonder how we can best strengthen students’ professional judgment, as some of my conversations with students have led me to believe that the development of engineering judgment is closely related with students’ professional identities. Both Riedner and Paretti have extensive experience with identity theories and have guided me patiently through an initiation to this space. I have also learned from them how writing can be useful in engaging students at the intersection between identity and judgment, and their expertise in writing scholarship has helped me immensely through this project and in revising my classroom approaches.

Riedner

As a writing scholar and former director of a writing in the disciplines program, I came to this project with an interest in understanding how threshold concepts from writing studies can enhance student learning in engineering fields. I’ve worked with faculty across disciplines who find that introducing concepts from writing studies and honed classroom practices from this field into their curriculum enhances student learning. In my experience, faculty find that focus on the writing process can improve student writing, and attention to threshold concepts from writing studies (i.e. genre, audience) improves student learning and success (Anderson et al. 2017). Moreover, in my experience working with STEM faculty, qualitative research on student writing enables faculty to understand and develop effective assignment design that

meets their curricular goals. This focus is particularly important in engineering where writing assignments can guide students towards developing disciplinary and professional judgement.

This NSF funded collaboration with Royce and Marie enabled me to expand my understanding of how assignment design in systems engineering that introduces students to disciplinary genres can begin the process of students learning professional judgement. Discussing scaffolded assignments with Royce that guide students through complex decision-making process, has helped me understand how writing assignments are means for students to practice and articulate professional judgement. The role of writing feedback (both learning to give good feedback and learning to judiciously incorporate feedback), enables me to understand how writing scholarship on peer review can benefit engineering pedagogy, but also to understand how engineering's focus on judgement opens up new horizons for writing pedagogy. Marie's expertise in engineering education has opened up my understanding of research and scholarship on the transition from university to professional work in STEM fields. Marie's discussion of research in engineering in this area has helped me understand how to prepare engineering students for post-graduate work (Winsor 1996).

Collaboration with Royce and Marie has expanded my understanding of how different disciplines approach student learning and how writing studies scholarship can expand this learning. My collaborators have also expanded my understanding of discursive constructions of disciplinary identity in engineering that has opened up new areas of inquiry and new areas for research.

Paretti

Although I entered this project as the "engineering education research mentor," it has also been a significant learning experience in two particular dimensions: conceptions of engineering judgement and re-engagement with writing studies. First, talking and writing about the question of engineering judgement have reshaped my understanding of what the terms means and how it can be enacted in discourse. Although I'd begun thinking about decision-making among engineers in a previous project, my definitions and understanding of the term were naïve and simplified. But as the three of us collaborated on a recent literature review paper and Royce brought in a range of studies about the concept of professional judgement, I began to understand more and more about the complexity of decision-making through systems engineering and cognition. For example, while engineering education researchers talk about close-ended problems as highly constrained with a single solution path and solution, closed-looped decision is characterized by the presence of feedback, uncertainty, ambiguity, and conflicting objectives. Thus open-ended problems such as those seen in industry involved closed-loop decision making. The role of feedback, in particular, has reshaped much of my thinking about how engineering students do, and might, learn to develop the judgement needed for making decisions in professional, open-ended contexts and created not only new avenues for research, but potentially new frameworks for exploring salient research questions.

Second, though I have background in writing studies, much of my recent work in this space has centered only on engineering students and the transition to professional work. discussions surrounding our analysis of the interview data have not only re-engaged me with the broader field of writing studies, but also helped me re-think the relationship between writing and identity through a closer examination of authorial stance. The kind of dramaturgical (Miles et al., 2014) and thematic coding we have been working on together, as well as number of sources introduced or re-introduced to me through Rachel's work, in particular, have challenged me to look beyond a familiar set of frameworks to see where current research in writing studies is taking the field as well as how strands of research from other related fields inform what we do. This mutual engagement has also pushed me to think again about the ways in which close readings of texts reveal the ways in which authors position themselves relative to their work and their fields. Dramaturgical coding, in particular,

though detailed in a common methods reference for engineering education research (Miles et al., 2014), is not widely used in the field and offers potentially interesting avenues for re-examining discursive constructions of identity not only in terms of engineering judgement, but in terms of a full range of engineering practices.

Both of these transformations have involved not simply new knowledge, but shifts in my own identity as an engineering education researcher, expanding my focus, re-establishing connections to the community of writing researchers and opening doors into new segments of that broad field.

A Negotiated Community of Practice

Across the experiences of the three authors, our mutual engagement with one another over the course of this project has markedly shifted both the joint enterprise and the shared repertoire of our work. Both the research questions and underlying constructs (i.e. what we mean by engineering judgement, identity, writing, discourse) have been continually negotiated and redefined as we each brought literature from different fields to the group for shared reading and learning as we collect, analyze, and interpret the data. The processes of both writing the literature review paper and analyzing the interview transcripts through multiple lenses have not simply enculturated Francis into “engineering education ways of doing things.” Rather, the synthesis of literature from a wide range of fields, the negotiation of codebooks as well as application of codes, and the processes of constructing meaning by bringing the literature and the coding into dialogue with one another to support the process of making meaning have all contributed to the ways in which we understand this joint research enterprise and the repertoire of terms, frameworks, and methods relevant to this and future studies. And these shifts, in turn, have shaped our own identities as scholars – in engineering education, but also in engineering and in writing studies. We have seen our individual and our shared work through new eyes, with new research questions and new research frameworks that we can now bring not only to this project, but to future projects inside and beyond engineering education.

Implications and Conclusions

More than a decade ago, Borrego et al. characterized collaborations between technical engineering and social science scholars as a process in which the engineers brought the problems and the social scientists brought the methods and frameworks. New engineering education researchers thus learned the research practices of the field, while established education researchers developed deeper understandings of the context and the nuances of engineering teaching and practice. In our collaboration, the process has been far more complex. At the heart of this complexity has been a rich and varied practice of mutual engagement in which we have engaged in practices that support joint learning and ongoing negotiation of the research project itself, including

- explicitly discussing our epistemological background and perspectives, looking at points of convergence and divergence to better understand both one another and the nature of the research questions at hand;
- reading and engaging meaningfully with prior research from one another’s fields;
- maintaining openness to ways of analyzing data, including attending to both alternate methods and alternate frameworks for addressing the research questions
- testing out varying methods and frameworks in different conference papers, including conferences in both engineering education and writing studies;
- discussing research design and preliminary results with other writing-in-STEM researchers in a learning community to better understand the breadth of potential uses of our chosen frameworks in other fields.

The results of these practices has helped to build engineering education capacity in multiple ways, expanding not only who does this work (including Francis and Riedner), but also, for all three authors, what the work is and how we might ask and answer questions in ways that

contribute to the practice of engineering education and expand our knowledge of what engineers do and how they learn to do it. In our experiences as a community of practice, the transformations moved well beyond Francis and Riedner learning “engineering education research methods” and Paretti learning “classroom problems.” Instead, our collaborative work has helped redefine for each of us what engineering education research is, how we do it, and how we understand our own relationships to it.

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