International perspectives on the need for interdisciplinary expertise in engineering education scholarship

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Abstract: *We report selected results of a joint initiative between the European Journal of Engineering Education and Journal of Engineering Education titled Advancing Global Capacity for Engineering Education Research (AGCEER). Over 300 individuals at ten conferences discussed questions about the present and future of engineering education scholarship, including needed expertise, existing and desired infrastructures, and leading research areas. In this paper, we report on perceptions of interdisciplinarity within and beyond engineering education research and scholarship. Participants emphasized the value of both educational research expertise and engineering pedagogical content knowledge, cited a number of methodological benefits of interfacing with the social sciences, and identified barriers to collaboration, such as language differences. We conclude with implications for engineering education scholars seeking to enlist education and social science expertise, particularly in the form of collaborators.*

Introduction and literature review

The purpose of this paper is to better understand the need for interdisciplinary expertise and collaborations in engineering education research and scholarship—as described by engineering education stakeholders attending AGCEER sessions around the world—and to make constructive suggestions, grounded in the literature, for enlisting education and social science expertise in engineering education scholarship. We begin with a review of the relevant literature, then present background on AGCEER, data collections and analysis, and our findings and recommendations.

In a study of US engineering faculty learning educational research methods, Borrego concluded, "In the absence of individuals trained in both engineering and social science methods, a team of collaborators with diverse disciplinary backgrounds is required to provide the necessary expertise for rigorous engineering education research" (2007, p. 95). Other prominent spokespersons have also advocated research collaborations between discipline-based researchers, from both within and beyond engineering (Wulf & Fortenberry, 2007). This mode of collaboration appears highly compatible with the kinds of discipline-based training systems that dominate higher education, particularly in the US. It is also more familiar to researchers from engineering fields who are already accustomed to similar kinds of collaborations in technical research.

While most fields in the social sciences and humanities are low consensus in character, many engineering and science disciplines can be described as high consensus fields due to relatively high levels of internal agreement, particularly as related to research agendas and curricula (Becher, 1987).

Evidence suggests that this unity also helps enable larger and more effective research collaborations in engineering and the sciences (Pfeffer, 1993). Lodahl and Gordon (1972), for example, found that high consensus and well-defined terminology in fields like chemistry and physics enable multidisciplinary divisions of labor. As a result, collaboration – measured by multi-author publications – occurs more frequently in technical fields (Bayer & Smart, 1991; Beaver & Rosen, 1979; Biglan, 1973).

However, such collaborations have been criticized in the interdisciplinary research literature as lacking sufficient integration to merit the label of true interdisciplinarity (Klein, 1990; Rhoten, 2003). In other words, far too many "interdisciplinary" engineering research projects are actually *multidisciplinary* in nature. Engineering and science are, in a sense, *too* well-organized. Oftentimes this criticism focuses on "instrumentalism," or dividing work and distributing tasks among experts (Muis, Bendixen, & Haerle, 2006). By contrast, collaboration is often more "truly interdisciplinary" in lower consensus social science and humanities disciplines because researchers in these fields must work more closely to agree on methods and interpretations (Lodahl & Gordon, 1972).

Combining these findings with more recent literature that differentiates multidisciplinary divisions of labor from truly integrated interdisciplinary collaborations (Committee on Facilitating Interdisciplinary Research, 2005) suggests that different disciplines might see differences in productivity, creative breakthroughs, and satisfaction with interdisciplinary collaborations (Borrego & Creamer, 2007). Most relevant to this analysis, however, is the finding that successful and sustained collaborations must consider and contribute to the career goals and rewards of all collaborators (Borrego & Newswander, 2008; Creamer, 2003) and that all collaborating disciplines must be equally valued (Bauer, 1990).

Further, such collaborations should be able to accommodate new graduates of engineering education PhD programs, as well as the many scholars who already identify as hybrid engineering-education researchers. Thus, engineering education scholars will increasingly need to understand and anticipate that their collaborators may have very different identities as researchers, background knowledge and expertise, expectations about time spent developing projects, motivations for collaborating, and desired research outcomes. Further, a balance must be struck between the expertise of various collaborators and the need to maintain objectivity so that assessment results are not biased to emphasize only positive findings.

Because education and other social science fields typically feature lower consensus and cultural status than engineering (Cole, 1983), we expect engineering education scholarship to be perceived by engineering faculty and administrators to be less credible, valuable, or significant than other types of engineering specializations. These challenges are further compounded by the field's interdisciplinary character, especially as status dynamics surface in collaborations among social science researchers and engineers. These issues and others are evident in our data.

Methods

Setting and Participants

The setting for this study is Advancing the Global Capacity for Engineering Education Research (AGCEER), a joint initiative by the *European Journal of Engineering Education*, published by the Société Européenne pour la Formation des Ingénieurs, and the *Journal of Engineering Education*, published by the American Society for Engineering Education, which consisted of special sessions at ten international conferences (Table 1) (Lohmann, 2008, p. 1). The exact questions and procedures for the sessions are described elsewhere (Borrego, Jesiek, & Beddoes, 2008; Jesiek, Beddoes, & Borrego, in review). Participants listened to brief presentations by 1-4 guest speakers, then discussed 1-3 questions in groups and reported back. In each case, one member of each group took notes and submitted them to session organizers. AGCEER participants (Table 1) are typical engineering education conference attendees: staff interested in improving their teaching or presenting their scholarship of teaching and learning, engineering deans, heads of schools or departments, researchers and other scholars who study engineering education, and industry/government employees.

Table 1. Conference Sessions and Number of Participants

Conference, Date, Location	N	Abbrev.
1st SEFI-IGIP Joint Annual Conference, 1-4 July 2007, Miskolc, Hungary	21	E1, European 1
6thGlobal Colloquium on Engineering Education, 1-4 October 2007, Istanbul, Turkey	45	GC, Global Colloquium
1st International Forum on Engineering Higher Education, 8-10 November 2007, Hong Kong, China	37	HK, Hong Kong/China
2007 Australasian Association of Engineering Education Conference, 9-12 December 2007, Melbourne, Australia	21	A, Australasia
2008 American Society for Engineering Education Annual Conference and Exposition, 22-25 June 2008, Pittsburgh, USA	53	US
2008 SEFI Annual Conference, 1-4 July 2008, Aalborg, Denmark	29	E2, European 2
37th International IGIP Symposium, 7-10 September 2008, Moscow, Russia	9	E3, European 3
COBENGE 2008, 8-11 September 2008, São Paulo, Brazil	42	B, Brazil
7th Global Colloquium on Engineering Education, 20-24 October 2008, Cape Town, South Africa	13	SA, South Africa
38th Indian Society for Technical Education National Annual Convention, 13-15 December 2008, Bhubaneswar, India	23	I, India

Data collection and analysis

Session organizers made audio recordings of the report back portions and collected note pages from each group. Human subjects (IRB) approval was secured to use these recordings, their transcriptions, and notes as data sources. We applied thematic analysis (Boyatzis, 1998) to categorize and understand the textual data of report back transcripts and note pages. According to an open coding procedure (Strauss & Corbin, 1998), codes (the rows in Table 2) were created as necessary to capture issues raised in each of the sessions. Two of the authors worked together to develop the initial list of codes using three session transcripts. Once the coding scheme was agreed upon, one author applied it to all transcripts and note pages, while the other two authors checked her work. All three authors worked together to confirm the findings by triangulating them with our related research and the literature (Patton, 2002). This paper focuses primarily on relationships between academic research fields. Relations with other engineering disciplines are discussed elsewhere, since particularly in this data set, engineering relationships were focused more on research-practice dynamics. The final coding scheme appears in Table 2. Note that with qualitative data of this type, it is inappropriate to provide frequency counts for each session. Further, some frequency counts would be artificially inflated for those groups that listed specific topics or issues on their note pages and also mentioned them in their report back.

Table 2. Summary of interdisciplinary issues and themes discussed at AGCEER sessions

	E1	GC	HK	A	US	E2	E3	B	SA	I
Interdisciplinary team collaborations	X	X	X	X	X	X	X	X	X	
Engineering knowledge, skills, and expertise					X	X	X	X	X	X
Knowledge from social sciences, humanities, and education	X	X		X	X	X	X	X	X	X
Learn from other non-engineering fields (education, math and science education)		X	X	X	X					
Knowledge of relevant literature			X	X	X	X			X	X
Research skills; Identify appropriate research questions, methods and theory	X		X	X	X	X	X		X	X
Evaluation/assessment knowledge		X			X			X	X	X
Knowledge of both quantitative and qualitative methods should be valued	X	X			X	X	X			
Knowledge of human subjects research ethics		X		X	X					
Employ rigorous methods		X	X	X	X				X	
Challenge of exchanges between engineering and non-engineering fields	X			X	X	X	X			
Shared language, culture, body of knowledge	X		X	X		X	X		X	

Results

Expertise and collaboration

At all sessions, participants agreed that engineering education scholarship requires knowledge and skills from the social sciences. Social and cognitive psychology, sociology, education, ethnic studies, women's studies, and international relations were all mentioned specifically. Other STEM or STEM education disciplines were only mentioned briefly. For instance, one group in the US session described math, physics and engineering sciences as foundations of engineering education, while a Global Colloquium group listed, "see what has been done in other disciplines, e.g. physics."

Interdisciplinary knowledge was not described as something that should be cultivated within a single person. Rather, participants consistently expressed a desire for interdisciplinary collaboration through teamwork. That is, they advocated teamwork between engineers and social scientists including educational researchers, each with individual disciplinary expertise, to conduct engineering education research. As European 2 participants explained, there is no "such a thing as an engineering education researcher. It was really a team effort because there were so many diverse areas that people were acknowledging that it should be a team that should be doing research."

Likewise, in European 3 it was argued that, "The first condition is to build a team between social scientists and engineering educators. No one can do it alone." And in South Africa, participants explained their rationale for advocating collaborative research in engineering education:

> In terms of … expertise … it takes a village or a team or an interdisciplinary group. The questions that face engineering education are so complex and involve so many different domains of expertise that it is rare and in fact probably almost impossible to find a single individual with the requisite expertise. So we think it actually takes a team.

Groups in Hong Kong/China and European 1 also discussed the need to include policy makers in multidisciplinary research groups. The lone exception to the idea that teamwork is necessary for EER came from a graduate student at the US session. He explained, "as an engineering education student who does both [engineering education and social science], I'm not quite sure where I belong I guess."

While participants emphasized the importance of multidisciplinary collaborations, many also worried about continued scepticism from engineers toward social sciences and educational research and felt the need to defend the inclusion of educational research in engineering education to their engineering colleagues. European 2 participants wrote that, "One very important quality is to have an OPEN mind to recognize that complementary expertise is VALUABLE" (caps in original). A South Africa group identified another possible benefit of involving social scientists: "There's also an outsider's perspective. We tend to actually as engineers get too close to the problem and someone coming from outside can take a more global view I think at times."

In addition, the widespread consensus observed across sessions regarding the importance of conducting engineering education research in multidisciplinary teams suggests that many participants believe that legitimate research demands the involvement of engineers. Various groups more specifically noted the importance of having: "engineering expertise" (South Africa); "deep disciplinary understanding" (United States); "specific subject expertise" (European 2); and "knowledge of engineering practice" (Brazil). One South Africa group added that it was important for researchers to have "familiarity with discipline and subject," including "thinking processes," "difficult concepts," "difficult material," "time frames and time stresses," "resources … necessary in the teaching environment," and "students."

Overall, participants seemed to have nuanced understandings of how the contributions of multiple disciplines complement and balance each other. Social science researchers know methods and theories and can be more objective outside observers, but engineers have a deep understanding of the setting and technical content. Nonetheless, participants were particularly adamant about the importance of engineering expertise in engineering education research, and for the most part they associated deep understandings of engineering and the social sciences with distinct populations of researchers.

Methods expertise

There were several types of methodological expertise that participants listed in a general way, but in each case, at least one group tied this expertise to social science. These included: knowledge of the literature base, research skills, quantitative and qualitative methods, evaluation/assessment, and rigour. Literature was mentioned at the majority of sessions, either to "know what's been researched," or more specifically to understand how education research applies to engineering.

Research skills at various stages were listed at nearly all the sessions: "Not show and tell—need research questions, hypotheses" (Australasia), "What is a good research question?" (European 2), "operationalize the question and look for the right instruments" (E3), "linkage to theory" (Hong Kong and US), and "marry the research questions with the methodology to answer them" (South Africa). Participants at five sessions dominated by European and US scholars emphasized both quantitative and qualitative methodologies, and statements at the US and European 3 sessions linked these methods to social science expertise, for example, "knowledge of the methods of empirical social sciences (qualitative, quantitative methods, statistics)." One US session group similarly cited the "need to apply existing validation and verification methods in social science to this engineering education context."

Challenges to collaboration

It was also clear from the responses that participants at the Australasian, European 1, 2 and 3, and US sessions were well aware of the potential challenges of interdisciplinary exchanges. Problems cited included perceived lack of rigour in educational research, language barriers, and authority and credibility ("shall a psychologist tell an engineer what to do?" asked one Moscow group). Participants at these sessions plus Hong Kong/China and South Africa elaborated on the need for a common language and culture between engineering and education. European 1 participants stated, "we need to have a common vocabulary, a common way of thinking, a way to be able to describe what we are talking about to each other."

Discussion and conclusion

The data presented here indicate strong support for bringing social science expertise to engineering education to augment engineering pedagogical knowledge. Such expertise would contribute methods, theories, and other important research skills to augment the quality of engineering education scholarship. However, there remain many challenges with such interdisciplinary exchanges, most notably language and cultural differences to be bridged, as well as status differentials between fields.

As the global character and core of engineering education scholarship continues to develop, strategic collaborations and translations will also need to happen within and across disciplinary boundaries. As noted above, interdisciplinary collaborations in engineering education research and scholarship are often assumed to involve multidisciplinary teams, including engineers and social scientists. To scale up the number, size, and success of such teams, leading researchers will need to enlist colleagues from a range of fields and then develop shared fundamentals and common vocabularies for their work. Such teams will also need to accommodate the growing number of engineering education researchers who have in-depth formal training in both engineering *and* the social sciences.

On one hand, such efforts can support continued efforts to articulate and develop the field's global core, including to nurture shared understandings of important theories, methods, and research areas. On the other hand, participating researchers should translate and share their results in other relevant disciplines and research fields. Such efforts can improve the visibility of their work, generate expanded interest in the field, and demonstrate how engineering education both draws from and informs other research fields.

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