Identifying Opportunities for Multinational Collaborations in Engineering Education Research

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Abstract*: We report on the results of a study to identify engineering education research areas likely to benefit from multinational collaboration. Our findings will inform the organization of three workshops intended to promote international research collaborations. This paper has two major aims. First, we discuss the three research areas selected for these workshops, including how we arrived at those topics and the modes of collaboration best suited to each. Second, we analyze a large collection of conference papers and journal articles to report on research trends in the specific area of electronic or e-learning, which will be the focus of a workshop in Australia in December of 2009. Current approaches to e-learning research in engineering education are described, and recommendations for future work are suggested.*

Introduction

In many traditional science and engineering disciplines, international collaborations often develop naturally around specific research areas, often encouraged by various regional and cultural synergies. Fields like science education have also been described as developing internationally (Fensham, 2004), while multi-institutional, multi-national research has been proposed as a marker for the emergence of computer science education as a "research-based discipline" (Fincher & Tenenberg, 2006). However, the relative newness of engineering education research means that we have not yet identified the key research areas most likely to benefit from international collaboration, especially as the field's definition and trajectory are still being negotiated locally. Extensive networks are not currently in place to connect faculty in different countries interested in similar engineering education research areas. Previous initiatives have also not served to initiate many international research collaborations, and prior results reveal significant cross-national and cross-regional differences in the definitions, identities, and educational systems of engineering (Downey & Lucena, 2004; Lucena, Downey, Jesiek, & Ruff, 2008). To develop sustainable international engineering education research collaborations, we must understand similarities and differences across countries and regions to anticipate and overcome barriers to collaboration, while also identifying the specific benefits that come from working together.

In this paper we describe our efforts to identify research areas most likely to benefit from collaboration, as well as the potential modes of collaboration identified through our research. A major product of this research will be three workshops funded by the US National Science Foundation. After discussing how we identified areas and modes of collaboration likely to benefit from a workshop, we delve more deeply into one of those areas: electronic learning (e-learning). Systematically analyzing the diversity of approaches being used to study e-learning in engineering education around the world helps us better understand how

this research area is conceptualized, while also improving our ability to design a workshop that will promote multinational collaborations.

Literature Review

Scholars in other disciplines have identified many possible benefits of internationalizing research fields, as well as some of the risks and detriments associated with failing to do so (Borrego, Jesiek, & Beddoes, in review). Some of these benefits also reveal possible modes of collaboration. For instance, comparative assessments, joint curriculum development, dissemination of best practices, setting and promoting international standards, and international exchanges of faculty and students (Wheeler, Smith, Rydant, & Larin, 2005) can all be understood as modes for, and/or outcomes of, collaboration. Yet as some have argued, collaboration has been widely under-theorized in the academy, including in terms of its associated power dynamics and relations (Durbin, 2009). Durbin, for example, has proposed an ecological mode that highlights the concepts, actors and methods that are frequently involved yet largely hidden in collaborative relationships. Graduate students and research subjects are two examples of such actors. He proposes that by reflecting on these hidden features when we think about and characterize collaboration, we can become better scholars, citizens, and collaborative partners.

Research Questions and Methods

The questions to be addressed by our research are: (1) Which specific engineering education research areas are most likely to benefit from targeted international collaboration?, (2)What are proposed modes for mutually beneficial engineering education research collaboration?, and (3) What modes of collaboration are most likely to benefit e-learning specifically? To begin addressing these questions, we have conducted an in-depth bibliometric study of English-language engineering education journal articles and conference papers published 2005-2008 in: *Australasian Journal of Engineering Education, European Journal of Engineering Education, International Journal of Engineering Education,* and *Journal of Engineering Education* (non-U.S. authors only), *Proceedings of the Australasian Association for Engineering Education Annual Conference, Proceedings of the ASEE Global Colloquium on Engineering Education,* and *Proceedings of the European Society for Engineering Education (SEFI) Annual Meeting*. The database includes more than 800 empirically grounded publications from 54 countries.

Our REES 2008 presentation highlighted both preliminary insights and limitations from our initial efforts to use author-defined keywords to identify publication patterns in engineering education research (Jesiek, Borrego, & Beddoes, 2008). In the subsequent analysis reported here we focus on identifying research areas with strong potential for international collaboration. First, institutional affiliations of authors were used to conduct counts of papers from each country represented in our dataset. We identified leading countries as those with ten or more papers in the database, which included: Australia, Belgium, Canada, Denmark, Finland, Germany, the Netherlands, New Zealand, South Africa, Spain, Sweden, Turkey, UK, and US. We then reviewed meta-data (titles, abstracts, and keywords) for each paper to determine leading areas of research within these fourteen countries. (It should be noted that the threshold of ten articles from each country is further subdivided by research area, which precludes including other countries in this analysis phase. However, researchers and publications from other countries are not necessarily excluded from the later phases of our analysis.)

The three authors iteratively reviewed the meta-data for this subset of papers to refine descriptions of the most frequently discussed engineering education research topics in each of the leading countries. These descriptions were triangulated with interviews, field notes, and recordings from international engineering education conferences. The lists of topics were then compared across countries to identify potential topics for international research collaboration (i.e., when the same or similar topics appeared for more than one country). More careful reading of the database entries, complemented with targeted supplemental research, refined our understanding and description of how the most common research areas are conceptualized and researched in each country or region. Comparison between two or more countries investigating the same research area then gave rise to a description of more generalized modes of collaboration.

This process led to the following six location-topic combinations as workshop possibilities (specifically for collaboration with US researchers due to the nature of our funding):

- Australasia: e-learning
- Australia: project/problem-based learning (PBL)
- Canada: design education and/or student teams
- Europe (primarily Denmark): project/problem-based learning (PBL)
- Europe (primarily UK): work/co-op based learning
- Europe: women in engineering

Many practical considerations had to be taken into account when narrowing this list to three workshops. For example, we needed colleagues and an existing conference in each location to help organize the workshop locally, a sufficient number of currently active researchers to attend the workshop (especially given that our funding prohibits financial support for non-US participants), and a geographic distribution of the workshops. These considerations meant that we specifically targeted topic-location combinations where we could work in tandem with larger conferences. Ultimately, we decided to hold one workshop on PBL in Europe, one on gender and diversity in Europe, and one on e-learning in Australasia.

We also recognize the limitations of our methods. The articles in our dataset represent only four years worth of English-language publications. Additionally, current work may not be published yet, some research areas straddle other disciplines and the work may be published elsewhere, and smaller countries may be disadvantaged by our threshold of ten articles. However, the relatively small financial and human resources available for this research meant that we analyzed as many publication outlets as possible with reasonable effort. We sought out a small but intentionally diverse sample of publications from around the world and selected a minimum threshold to avoid making sweeping generalizations about a given country or region. We also hope to attract diverse regional participation in our planned workshops, including from countries not well represented in our database.

Theoretical Framework

Our study takes theoretical insights from the sociology of science, which helps us understand how large-scale patterns of scientific and technical research are related to the more localized practices and activities of researchers and research groups (Fujigaki, 1998; Hess, 1997). Fujigaki more specifically argues that performing large-scale studies of journal articles and conference papers is especially helpful in illuminating these kinds of local-global links, including across time and geography. Further, Fujigaki shows the value of using systems theory to conceptualize how networks of scientific researchers, publications, and publication outlets form, develop, and interrelate, especially as they reflect and reinforce the evolving boundaries of research fields.

Findings and Discussion

Modes of Collaboration

The first major outcome of our analysis was the identification of six specific engineering education research areas with strong potential for international collaboration. Based on both the topic-location combinations and additional considerations listed above, we narrowed our list to the following three workshop topics: PBL, gender and diversity, and e-learning.

A second outcome of this analysis is the development of modes of collaboration for international engineering education researchers. Once potential research areas are identified, there remain questions about determining optimal approaches to collaboration. We therefore identified several generalized modes of collaboration around the following facets of research: methodology, results, and theory. For example, methodological collaborations occur between researchers who are interested in the same topic area but use different methodologies, e.g. quantitative or qualitative. Research on PBL, gender, e-learning and many other areas of engineering education can benefit from this type of collaboration. A second type of

collaboration occurs when researchers share data and/or findings, including to generalize and/or perform comparisons across different settings or study sites. These types of collaborations can also involve bridging research and practice, such as when researchers work with seasoned practitioners to collect data or apply findings. A third mode for collaboration involves identifying shared theories or theoretical frameworks for research in a given area. We propose that this mode is most applicable in the area of gender research in engineering education, in part because of: 1) an observed lack of shared theoretical foundations and understanding in this body of literature (Beddoes, Borrego, & Jesiek, forthcoming, 2009), and 2) frequent differentiation between those who study gender in engineering and those who lead related programs and interventions.

Expanding international collaboration also presents opportunities to expand interdisciplinary collaboration. Beneficial interdisciplinary collaborations are most likely based on methodological or theoretical modes, as differences in research settings may make it difficult to compare data directly. For example, research on the use of PBL in medical schools and engineering schools may involve the use of similar theories or methods, but with a limited ability to share specific data or findings. Additionally, not all modes of collaboration are equally relevant to every potential international collaboration, nor do they always result in the same types of relationships. Each case will be different and will likely entail collaboration around one or two modes that hold the most potential for the research area and locations involved. Furthermore, different modes may lead to different types of international relationships. For instance, piloting a course or specific intervention in another country may help build interpersonal and institutional relationships, while borrowing theory or citing the work of an international colleague will likely have different impacts. Thus, the nature of collaborations and associated networks will shape the ways in which engineering education internationalizes as a field, especially by determining the nature of the relationships that are built.

e-Learning: Current Approaches and Future Opportunities

We now turn to one of our selected workshop topics, e-learning. Of 885 publications in our engineering education research database, 118 were related to e-learning. Information about the countries represented in the database is summarized in Table 1.

Table 1: Individual Country Counts and Multinational Collaboration Counts

Country	***No. of articles****		***Collaborating countries***	***No. of articles***
Australia	36		US + Taiwan	4
US	34		Australia + UK	1
The Netherlands	7		New Zealand + Canada + Taiwan	1
New Zealand	7		New Zealand + UK + US	1
UK	7		Sweden + US	1
Spain	6		UK + US	1
Sweden	4		US + China	1
Taiwan	4		US + France	1
Canada	3			
Germany, Hong Kong, Hungary, and Japan	2 each			
Brazil, Denmark, Finland, Israel, Italy, Latvia, Mexico, Norway, and Turkey	1 each			
* including multinational collaborations				

Also, as summarized in Table 1, only 11 of the 118 publications (or 9.3%) involved multinational collaborations. Multinational collaborations are most often the result of researchers working with colleagues at institutions where they formerly worked or studied. We suggest, therefore, that there is much potential for promoting cross-national collaboration given the large number of researchers interested in this topic.

We coded each paper based upon the primary approach(es) that the authors took. The approaches and the number of papers in which they appeared are summarized in Table 2. By far the most common type of research involved the description and assessment of an initiative undertaken by the authors. Examples include wikis, games, video conferencing, online courses and labs. This approach was broken down into more specific categories that are represented by the first, second, and sixth rows in Table 2. The next most common type of approach was to compare online and in-person learning gains and/or preferences. There were also researchers who were concerned specifically with strategies for assessing online learning, and many also discussed modes or frameworks for improving assessment. Also important for this discussion are the eight articles that took some general aspect of learning or a learning theory as their starting point, and investigated online learning specifically in relation to that theory. Examples include one article that investigated the relationship between different learning styles and e-learning and another article that was concerned with how communities of practice develop with e-learning.

Table 2:Frequency of approaches to distance education

Approach	*No. of articles**
describe and assess online learning and testing tools	77
describe and assess virtual lab	21
compare distance and in-person student learning and preferences	13
present mode/framework for assessment of online learning	11
study theory or learning more broadly (in distance ed context)	11
describe and assess learning with mobile devices	8
encourage faculty to use online learning effectively	7
present negative aspects or challenges of online learning	6

* total higher than 118 because some papers were coded into multiple categories

Our analysis reveals that research on e-learning has tended to emphasize specific interventions, coupled with assessment as necessary. The majority of researchers are currently focused on implementing and describing their own interventions and/or initiatives at individual universities. This is perhaps not surprising given that developing functional technological interventions in education often demands much time and energy. However, now that researchers are beginning to look beyond their individual interventions to ask questions about theory and assessment, generalizability (or at least situating results in an international landscape) will become more and more possible. Collaboration across international boundaries is one way to move beyond individual interventions and promote thinking about the possibilities and horizons of e-learning. One next step would be for researchers and other faculty currently focused on interventions to work with those international colleagues who are developing more advanced assessment methodologies, such as those whose work falls into the fourth row of Table 2. Since less than a quarter of the articles we analyzed are methodologically and theoretically focused, there is a great deal of untapped opportunity for research collaboration.

There are also opportunities to expand upon the observed trend of connecting e-learning with other important themes in engineering education. Within the distance education publications in our dataset, certain other themes were visible, including: problem and project based learning; teamwork and collaborative learning; lifelong learning; and green and environmental engineering. Perhaps most significantly, international education initiatives and collaborations are also a recurring topic in articles on

e-learning, suggesting that scholars are already thinking beyond national boundaries. We suggest that using online tools to foster the development of the technical and professional skills in these and other areas is an especially notable and forward-looking way to think about e-learning. However, innovative e-learning interventions should be accompanied by the development of robust theoretical foundations, systematic assessment strategies, and research on the potential generalizability of findings and transferability of successes. Cross-national collaborations can help support these types of goals, while also stimulating comparative research and establishing best practices.

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