

Expanding Global Engineering Education Research Collaboration

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Abstract

Within many traditional disciplines, international collaborations have developed around specific research areas. But since engineering education research is a relatively new field of activity, few international research collaborations in this area have yet emerged. As engineering becomes more global, these types of collaborations are increasingly important, especially to promote continued innovation in engineering education and ensure the employability and mobility of engineering graduates. In a current research project, the authors are working to identify specific engineering education research areas that would benefit from strong intellectual collaboration and partnerships between researchers from multiple nations and/or regions. Direct ethnographic observations and comparative publication analysis of conference proceedings are being used to analyze data from ten international engineering education conferences held in 2007 and 2008. This process will reveal the most frequently presented research topics at each conference, the nature of the problems being studied, and the research strategies being applied. The regions to be studied include Europe, North America, East Asia, Australasia, and (Southern) Africa. At the end of the project, we will summarize major engineering education research priorities and approaches within each region, including a discussion of overlapping interests and latent research opportunities. Ultimately, we will recommend possible models for cross-national and cross-regional collaboration, and use a series of ethnographic observations to discuss strategies for overcoming barriers and challenges related to social and cultural differences. In this paper we present preliminary results, with an emphasis on Europe, to validate our interpretations of engineering education research activities and opportunities in this region.

Keywords: engineering education, research, collaboration, cross-national, publication analysis

1. INTRODUCTION

Within traditional engineering disciplines, international collaborations have formed naturally around specific research areas, and funding support has helped to expand and deepen many such partnerships. However, since engineering education research is a relatively new area, we simply have not yet identified the key research areas most likely to benefit from international collaboration. Further, extensive networks are not currently in place to connect faculty from different countries who are interested in similar engineering education research areas.

Prior U.S.-initiated efforts to build engineering education research capacity, including Rigorous Research in Engineering Education (NSF DUE-0341127) [1-2], the Engineering Education Research Colloquies [3], and the first International Conference on Research in Engineering Education (ICREE) [4], have all focused on engineering education research in general and had limited international components. These efforts have not served to initiate many international engineering education research collaborations. In fact, such partnerships may be hampered by significant cross-national and cross-regional differences in the definitions, identities, and educational systems of engineering [5].

This diversity was evident at the 2007 ICREE conference. While participants benefited from discussing their work with attendees from other countries, it was apparent that their goals and value systems are different in ways that make international engineering education research collaborations more challenging than previously thought. This paper describes a current research project that uses observational data from a series of engineering education research panels, combined with an analysis of papers published in conference proceedings and journals, to identify opportunities and strategies for developing international engineering education research

collaborations. The preliminary results presented here discuss worldwide trends and developments in Europe, with the goal of validating our interpretations of engineering education research activity and opportunities.

Planned future work will expand these analyses, including by focusing on other nations and regions. We are also analyzing underlying similarities and differences in different parts of the world in order to anticipate and overcome barriers to collaboration, while identifying the ample benefits and opportunities that can come from working together.

2. THEORETICAL FRAMEWORK

Prior work on the sociology of science informs our study. More specifically, institutional approaches to science studies improve our understanding of large-scale patterns in scientific and technical research, including by time and by location [6]. Our analysis also benefits from three theoretical insights from Fujigaki [7]. First, studying papers published in journals and conference proceedings can reveal links between the everyday, local practices of individual researchers and the macro-scale paradigms and structures of science. Second, analyzing publications can help link quantitative research (using methods like citation analysis) and qualitative studies that examine both the content of articles (by means of publication analysis, for example) and the actual practices and interactions of researchers (such as documented via ethnographic observations and interviews). And third, the ongoing publication of journal articles provides evidence for how the boundaries around scientific research are established and maintained.

Following these insights, our study uses a mix of quantitative and qualitative methods, pays close attention to relating macro-scale trends with the activities of individual researchers and groups, and aims to help identify the boundaries around engineering education research.

3. RESEARCH QUESTIONS

The research questions for our larger research project include:

1. What kind of engineering education research is being done in what specific nations and regions worldwide? If we detect significant variability, how do we account for it?
2. Which specific engineering education research content areas are most likely to benefit American researchers through targeted international collaboration?
3. What are proposed models for mutually beneficial engineering education research collaboration?

A major goal of this work is to increase capacity for international collaboration within specific engineering education research areas. This paper presents preliminary results related mainly to the first of these questions.

4. METHODOLOGY

4.1. Data Sources

One main data source for this project is observations and proceedings from ten international conferences targeted by *Journal of Engineering Education* and *European Journal of Engineering Education* for special AGCEER panel discussions on engineering education research. These conferences represent regional diversity as well as a focus on engineering education, and provide data in the form of proceedings, lists of participants, detailed notes, and ethnographic observations. However, data for the present analysis is mainly taken from other journals and conference proceedings, including *International Journal of Engineering Education*, *European Journal of Engineering Education*, and *SEFI Annual Conference Proceedings*. For each, papers from 2005-2007 that meet our research criteria were included in our publication database and analyzed (with the exception of SEFI 2006, which we have not yet been able to obtain).

4.2. Data Analysis Methods

We begin our comparative publication analysis by first identifying systematic research publications for our data set. We exclude purely descriptive papers, such as those that discuss the development of modules, labs, courses, and or curricula. To do so, we started with these six criteria from *Scientific Research in Education* (Shavelson and Towne, 2002):

1. Pose significant questions that can be investigated empirically.
2. Link research to relevant theory.
3. Use methods that permit direct investigation of the question.
4. Provide explicit, coherent chain of reasoning.
5. Replicate and generalize across studies.
6. Disclose research to encourage professional scrutiny and critique.

Very few of the more than 800 articles in our preliminary data set listed concise research questions (criterion 1), identified a relevant learning theory (criterion 2), or explicitly discussed the more general relevance of results (criterion 5). Excluding all publications that did not meet all six of these criteria would have severely limited the size of our database and the generalizability of our research. We therefore adjusted our criteria to simply require that qualifying papers present empirical data (most often in the form of surveys or learning assessments). In future research we intend to evaluate how many engineering education research articles meet which of the specific criteria listed above.

For each paper meeting our expanded definition of engineering education research, institutional affiliations of authors were used to identify country (or countries) of origin. Keywords (author-identified, or researcher-generated based on titles and abstracts), supplemented by a search and review of relevant paper abstracts, are allowing us to develop 5-10 leading problems being addressed by engineering education researchers worldwide. Cross-referencing country and keyword data will show what types of research are being done where, while ethnographic observations will help us understand the reasons for these patterns. And finally, observational data and publication analysis will reveal the strategies that researchers in different countries and regions are using to solve these research problems, thereby pointing to opportunities for mutually beneficial collaborations.

5. FINDINGS AND DISCUSSION

5.1. Qualifying Papers and Trends Over Time

As summarized in Table 1, 280 of 833 articles (or 34%) in our current data set qualified as research according to the basic criteria described above. Papers published in the *IJEE* qualified most often, and exhibited a strong upward trend from 31% in 2005 to 51% in 2007. *SEFI* papers reflected a similar trend, increasing from just 9% in 2005 to 28% in 2007. This increasing emphasis on research parallels broader shifts, including active efforts to promote engineering education research by UNESCO's International Center for Engineering Education (UICEE), the European Society for Engineering Education (SEFI), and the European Union's thematic network on Enhancing Engineering Education in Europe (E4) and its successor Teaching and Research in Engineering in Europe (TREE). Similar trends in the U.S. include the research orientation of the *Journal of Engineering Education* [9-10] and organization of the aforementioned ICREE meeting [4, 11].

| Source and Year | Total No. of Papers | Qualifying Papers | Percent Qualifying |
|--|---------------------|-------------------|--------------------|
| <i>International Journal of Engineering Education (IJEE)</i> | | | |
| 2005 | 128 | 40 | 31% |
| 2006 | 148 | 64 | 43% |
| 2007 | 133 | 68 | 51% |
| <i>European Journal of Engineering Education (EJEE)</i> | | | |
| 2005 | 45 | 14 | 31% |
| 2006 | 64 | 20 | 31% |
| 2007 | 62 | 19 | 31% |
| <i>Proceedings of the SEFI Annual Conference</i> | | | |
| 2005 | 80 | 7 | 9% |
| 2006 ¹ | N/A | N/A | N/A |
| 2007 | 173 | 48 | 28% |
| Totals for all Articles | | | |
| 2005-2007 | 833 | 280 | 34% |

¹ SEFI 2006 proceedings were not available at the time of publication.

TABLE 1. Number of Qualifying Research Papers by Publication, 2005-2007

IJEE editor Michael Wald has explicitly positioned his journal in relation to these trends. In early 2006, for example, he noted the role of the *IJEE* in "promoting pioneering and research based ideas for the future of

engineering education” [12] Later that year, he indicated that many of the papers published in a special issue of the journal met seven possible criteria for “engineering education research” [13]. Wald has also repeatedly questioned the value of publishing descriptive case studies. In mid-2007, for example, he stated that the journal was only interested in “best practice” papers that were “really innovative and analytical.” [14]. And with the *IJEE* now receiving more than 1000 submissions a year but publishing fewer than 150, the editors can clearly privilege work that meets these types of benchmarks.

In contrast, the number of *EJEE* articles meeting our criteria for research remained at a constant 31% for all three years. However, evidence suggests that this journal is also raising its profile. In a 2007 special issue, for example, a guest editorial indicated that the included papers were working at the “highest scientific level” [16]. The journal’s increasing emphasis on research is also reflected in a special issue on “Educational Research Impacting Engineering Education,” planned for 2009 [17]. And *EJEE* review criteria were expanded, likely in early 2007, to explicitly include “originality and innovation potential” and “quality of the scientific evidence presented” [18].

5.2. Research Activity by Country

Country-of-origin information for all 280 qualifying articles in our data set is presented in Table 2. As indicated, 118 papers (or 42% of all papers) included one or more authors affiliated with U.S. institutions. Of these papers, the vast majority (106) were exclusively authored or co-authored by U.S.-based authors. Authors or co-authors currently affiliated with member countries of the European Union (EU) were listed on 112 (or 40% of all) qualifying articles. The top three author locations in the EU were the United Kingdom, Spain, and Netherlands.

| Country ¹ | No. of Papers | Country | No. of Papers | Country | No. of Papers |
|----------------------|---------------|-----------|---------------|-------------------------|------------------------|
| United States | 118 | Israel | 5 | Brazil | 1 |
| United Kingdom | 24 | Hong Kong | 4 | Chile | 1 |
| Spain | 18 | Portugal | 4 | Czech Republic | 1 |
| Turkey | 16 | India | 3 | Japan | 1 |
| Netherlands | 13 | Norway | 3 | Kuwait | 1 |
| Australia | 12 | Mexico | 3 | Malaysia | 1 |
| Germany | 10 | Slovakia | 3 | Oman | 1 |
| Sweden | 9 | Taiwan | 2 | Palestine | 1 |
| South Africa | 8 | Belgium | 2 | Poland | 1 |
| Finland | 7 | Greece | 2 | Romania | 1 |
| Canada | 6 | Latvia | 2 | Slovenia | 1 |
| Denmark | 6 | Lebanon | 2 | Ukraine | 1 |
| France | 5 | Russia | 2 | | |
| | | | | Total – All Data | 301² |
| | | | | Total – EU Only | 112 |

¹ Shaded cells indicate European Union (EU) member countries.

² Total is larger than total papers (n=280) due to double counting of multi-authored papers.

TABLE 2. Number of Qualifying Research Papers by Country, 2005-2007

We are now beginning the challenging task of explaining these trends, but additional research provides some clues. In 2007, for example, *IJEE* editor Michael Wald noted the relatively large number of articles from the United States, United Kingdom, and Spain being published in his journal [19]. He worked to explain this fact by pointing to contributing factors like the establishment of engineering education innovation centers in Spain and substantial National Science Foundation (NSF) support for research in the United States.

Other research by Lucena, Downey, Jesiek, and Ruff also suggests that engineering education research can only emerge as a field when a given region or country comes to agree on what competencies are desired for its engineering graduates [20]. When this happens, engineering education research can focus on achieving those competencies. This may provide an explanation for differential levels of research activity, including high levels in Europe where the Bologna Declaration and so-called “Dublin Descriptors” are building consensus around, and stimulating research on, common competencies. Reflecting this trend, an *EJEE* editorial published in 2006 introduced a series of research papers that dealt with various aspects of competency in engineering education [21]. In the United States, ABET EC2000 accreditation criteria have arguably done even more to standardize competencies and promote related research.

Author data also provides some tentative insights about collaboration patterns in engineering education research. For all qualifying articles, just 20 of 280 (or 7%) listed authors from multiple countries. Of these, 19 involved co-authors from two different countries, while just one article included authors from three countries (the United Kingdom, Australia, and the Netherlands). The countries most often involved in these collaborations included the United States (12 of 20), the United Kingdom (4 of 20), and Germany (4 of 20).

We hypothesize that these research collaborations often grow out of pre-existing cross-national relationships, including between individuals (such as faculty-faculty and faculty-student relationships) and institutions (especially through formal university-university partnerships and exchange programs). For example, one article in our data set reports on joint research by faculty at Iowa State University, USA and University of Technology of Compiègne, France. This work may have been stimulated by a formal study abroad relationship between the two institutions [22]. We are now working to learn more about how these and other partnerships typically form.

The papers in our database, as well as our ethnographic observations, also reveal the lasting imprint of colonial relationships. Engineering education researchers from the UK, for example, appear more likely to collaborate and attend events with their colleagues from former British possessions, such as Hong Kong and Australia. Similarly, ethnographic observation at the 2007 Australasian Engineering Education conference revealed that engineering educators in this region openly discuss how they look to the UK and others for leadership.

5.3. Keyword Analysis

The challenges of keyword analysis make it difficult to identify leading areas of engineering education research, especially by region and subject. For example, in some contexts assessment may refer to outcomes-based evaluations of courses and curricula, while in others it can mean techniques for grading student work. Others have noted the wide range of meanings associated with terms like “competency” and “skill” [21]. However, our preliminary analysis reveals eight major areas, in roughly decreasing order of keyword prevalence:

- *Curricula*, including development, evaluation, and reform at all levels (courses, programs, etc.)
- *Assessment*, including outcomes-based and competency-oriented
- *Engineering design*, including teaching and learning design-related skills, processes, tools, etc.
- *Collaborative, cooperative, and team-based learning*
- *Problem-, project-, and inquiry-based learning*
- *Educational technologies*, including for teaching, learning, distance education, etc.
- *Diversity*, particularly with respect to gender and ethnicity
- *Laboratories*, developing and innovating in/for engineering education

An informal analysis of all articles in our data set with EU-based authors or co-authors suggests that these same eight areas are also prominent in European engineering education research circles, perhaps not surprising given our main sources. But this review also suggests a ninth interest area that is receiving significant research attention in the EU, namely *intercultural skills and global competency*. This finding likely reflects a growing need for engineers who can work across borders, both within and beyond Europe.

Additional analysis reveals other local variations. On the subject of diversity, for example, at least 16 papers included keywords related to gender themes, and involved authors from 11 different countries. By contrast, only four papers covering diversity topics included keywords related to ethnicity, race, and/or minorities. Further, these same four papers involved authors from only three countries: Germany, South Africa, and the U.S.

As noted above, papers dealing with assessment also reflect regional variations. In the U.S. and Europe, for example, agreement about competencies is likely stimulating related research. Additional data collected for this project similarly suggests that much engineering education research in Asia is being motivated by accreditation, or assessing specific learning outcomes. We hypothesize that assessment will be an important area for potential engineering education research collaborations between faculty in Asia and other regions. However, this potential may be hampered by a lack of national and regional agreements about desired competencies, compounded by a shortage of researchers performing leading-edge engineering education research. Further, sharing results and collaborating in these research areas may also raise concerns about how such activities improve and/or impair the global economic competitiveness of the participating countries.

6. CONCLUSION

This paper provides an early snapshot of our research results. We are now expanding our data set to include additional publications and ethnographic observations, while refining our keyword analysis to create a more fine-grained analysis of research areas by region and country. Models for research collaboration will continue to

emerge as we compare how different countries and regions approach specific challenges and problems in engineering education research. Comparing how these approaches may complement each other through collaboration will lead to the development of recommended “models of collaboration.”

We are finding, for example, that some regions have solved a problem that other regions or countries are just now beginning to face. Problem-based learning and remote laboratories, for example, are two research areas that are more developed in Europe and Australia than they are in the U.S. We also find that some regions or countries are solving problems differently (e.g., through quantitative or qualitative approaches). For instance, at the recent ICREE conference, an international researcher questioned the American focus on generating and validating concept inventories for studying conceptual understanding. This led to an engaging discussion about the core purposes of conceptual understanding research.

Promoting appropriate models for collaboration not only enhances this type of information sharing, it can also link researchers to new study sites, connect researchers to one another (including across disciplines and preferred methodologies), and expand the generalizability of research findings. Hence, our research results will be translated into concrete implications for the design of future interventions such as workshops. More specifically, the results will include a list of specific topics and regions to pursue for targeted collaborative research and capacity-building activities. Then, models for collaboration will suggest design principles for these activities. For example, if educators in one country have developed innovative learning spaces such as labs, it would be important for workshops to meet in that country so visitors could experience these spaces first-hand. We have recently secured funding to support further analysis related to these themes, and our findings will be used to organize an international meeting that will bring together participants from the United States and at least one other country to focus on 2-3 specific research areas.

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