Advancing Global Capacity for Engineering Education Research (AGCEER): Relating Research to Practice, Policy, and Industry

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BACKGROUND
We report on the 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). More specifically, we present findings from a series of moderated interactive sessions held at international engineering education conferences between July 2007 and December 2008, where participants were asked to discuss the current state and future trajectory of engineering education research.

PURPOSE (HYPOTHESIS)
How did AGCEER session attendees describe: (1) the relationship between engineering education research and educational practice, policy considerations, and industry, and (2) important stakeholders, mechanisms/strategies, and challenges for relating research to practice, policy, and industry?

DESIGN/METHOD
Thematic analysis was used to categorize and understand the textual data of report back transcripts and note pages from ten AGCEER sessions involving 300 participants on six continents. An open coding procedure was used to capture issues raised in each of the sessions on the relation of research to practice, policy, and industry.

RESULTS
We observed frequent discussion and widespread consensus among AGCEER participants about the need to relate engineering education research to the practice of engineering teaching. Discussions about relating research to policy and industry remain formative, but appear to be gaining traction.

CONCLUSIONS
We propose a cyclic model to better conceptualize how engineering education research can be strategically related to practice, profession, and industry across diverse local and global contexts.

EDITORS’ NOTE
Engineering education is developing into a domain meriting scientific study. Recognizing this development, the editors of the Journal of Engineering Education and the European Journal of Engineering Education, Jack Lohmann and Jean Michel, respectively, launched a worldwide initiative in 2007 called, “Advancing the Global Capacity for Engineering Education Research.” Over an 18-month period, workshops were held at 10 international engineering education conferences involving hundreds of persons. The authors of this paper provided leadership in the conduct of the workshops. They have sorted through the wealth of information collected and prepared this thoughtful paper, which was peer reviewed by both journals. Because of the significance of this contribution to the global development of this field, we are pleased to jointly publish this paper to reach both our journals’ audiences.

Erik de Graaff, Editor-in-Chief, European Journal of Engineering Education
Jack R. Lohmann, Editor, Journal of Engineering Education

I. INTRODUCTION
The field of engineering education research is going global. In 2008 the European Society for Engineering Education (SEFI) established a Working Group on Engineering Education Research (WG-EER) (SEFI, 2008), and the Australasian Association for Engineering Education (AAEE) is developing its own Educational Research Methods (ERM) group (Australasian Association for Engineering Education, 2008). Since 2003, the Annals of Research on Engineering Education (AREE) has served as a meta-journal and Web portal linking engineering and science education journals to an online scholarly community that is both lively and internationally diverse (AREE, 2010). Since 2001, a series of Global Colloquia on Engineering Education have been held by the American Society for Engineering Education (ASEE) and its partners in diverse locales, and the Society’s Journal of Engineering Education (JEE) is now published in partnership with nine international organizations and distributed in 80 countries, including publication of selected articles in Chinese and Korean for distribution in China and Korea (Lohmann, 2010). In many national and regional contexts, engineering education research is being bolstered by a growing array of conferences and workshops, courses, degree programs, research centers, funding sources, and publication outlets (Jesiek, Newswarder, and Borrego, 2009; Jesiek, Borrego, and Beddoes, 2009).

Yet, to what extent is engineering education research truly internationalizing as a field? As many scholars have recognized, emerging fields that lack a thoroughgoing international profile may be characterized by isolated researchers tackling similar
“obvious problems” using “relatively crude” approaches (Lemaine, et al., 1976, p. 5). Their research findings, if published at all, are likely scattered across disciplines and regions. As Lemaine et al. summarize, “Where informal communication is not established, growth appears to be seriously impeded” (1976, p. 6), as evidenced by data from the social sciences, e.g., small group research (McGrath and Altman, 1966) or international relations (Wæver, 1998).

In the engineering education research community, there appears to be growing awareness of the dangers of isolation, as well as the benefits of internationalization. Perhaps most notably, in 2007 the European Journal of Engineering Education (EJEE) and the Journal of Engineering Education (JEE) launched an initiative titled Advancing the Global Capacity for Engineering Education Research (AGCEER). Two of the leaders of this movement invoked a research and development (R&D) metaphor to explain both the importance of the initiative and benefits of cultivating a global community of engineering education researchers:

> The vitality of any discipline depends on a vibrant community of scholars and practitioners advancing the frontiers of knowledge through research and innovation. Just as engineering excellence depends critically on engineering research and development, excellence in engineering education depends critically on research and development in engineering education. However, globally, engineering education development is a more mature field in comparison to engineering education research which is still in its infancy, both in terms of its philosophical structure and physical infrastructure. Because research and development are mutually complementary activities each enhancing the other, there is a need to enhance the global capacity for engineering education research to better leverage the global developments in engineering education innovation (Lohmann and de Graaff, 2008, p. 1).

In line with this rationale, the initiative had multiple goals, among them: build a network of engineering education scholars and practitioners, report on the discussions in the sessions, identify infrastructures to sustain a global community, and initiate a new research summit. This paper more specifically examines how engineering education conference attendees around the world described the relation of engineering education research to what Lohmann and de Graaff termed “engineering education development.” In other words, we seek to better understand “engineering education research...[and] its role within scholarly inquiry and practice of engineering education based on the discussions in the sessions” (Lohmann and de Graaff, 2008). Our analysis also provides opportunities to observe how participants linked engineering education research to two other domains of “development,” namely policy and industry.

The setting for our study was ten AGCEER special sessions, held at engineering education conferences in Hungary, Turkey, Hong Kong, Australia, the United States, Denmark, Russia, South Africa, Brazil, and India. Participants were asked to answer questions about the current state and future trajectory of engineering education research, including needed expertise, existing and desired infrastructures, and leading research areas. Our inquiry and analysis was guided by the following research questions:

How did AGCEER session attendees describe:
- The relationship between engineering education research and educational practice, policy considerations, and industry?
- Important stakeholders, mechanisms or strategies, and challenges for relating research to practice, policy, and industry?

We observed generally high levels of agreement and consensus across AGCEER sessions, particularly regarding the benefits of connecting research to educational practice. Discussions about relating research to policy and industry, on the other hand, surfaced in some sessions but were underdeveloped. We also note some perennial challenges identified by participants, and propose a cyclic model to better conceptualize how engineering education research can be strategically related to practice, policy, and industry across diverse local and global contexts. As additional grounding for our analysis, we begin by reviewing existing literature on research-practice dynamics in the development of academic fields.

**II. Literature Review**

**A. Privileging Research over Practice in the Development of Academic Fields**

Many scholars have adopted and adapted Biglan’s (1973) classification scheme to categorize and compare academic fields (Becher, 1994). Biglan originally distinguished “applied” fields, which are mainly concerned with applying knowledge, from those labeled “pure,” which are focused on generating fundamental insights. Since both engineering and education are typically associated with the applied end of this spectrum, we can expect that engineering education is also often viewed as an applied field.

Many have also observed that disciplines often shift over time from the applied to pure. This “academic professionalization” happens as researchers move away from empirical reality and practice in favor of “basic” research, developing new theories, and making their work appear more scientific (Abbott, 1981, 2001). In fact, those who cultivate the most abstract forms of disciplinary knowledge and theory are often rewarded with the highest status and prestige (Abbott, 2001, p. 146). As summarized by Abbott, “applied work ranks below academic work because the complexity of professional practice makes practical knowledge ‘messy’ and ‘unprofessional’” (Abbott, 2001, p. 22). These trends are often synergistic with the gradual replacement of “theoretically-based curriculum at the expense of earlier practical emphases” (Blume, 1985, p. 148).

To the extent that many traditional engineering fields are closely linked to industry and the engineering profession, they are aligned with practice and again pulled toward the applied end of the disciplinary spectrum. But as academic engineering disciplines have become more theoretical and scientific—especially during the twentieth century—they have taken on a more “pure” character (Seely, 1993, 1999). Disciplines like business, law, and education similarly grew out of the applied realm, with basic research and abstract theory gaining prominence over time. In fact, there are lively discussions in the educational research community about the relation of research and practice, including whether there are problematic gaps between the two (Biesta, 2007). Concerns about this relation are also evident in fields like science education. Fensham
(2004) proposes “implications for practice” as one of fourteen criteria for evaluating the development of science education as an academic field, although the rest of his criteria are focused on structural factors (journals, conferences, etc.) and evaluating the quality of research.

B. Relating Research and Practice in Academic Fields

While research and practice are sometimes described as opposing forces or tendencies, some commentators have framed them in more complimentary terms. Since the 1990s, for instance, broader concerns about relating basic scientific research and technological innovation helped spur the development of some influential research-practice frameworks. For example, Stokes (1997) proposed categorizing research based on whether it is driven by: (a) practical needs or uses, and/or (b) a desire for fundamental knowledge or understanding, as shown in Table 1.

Building on one historical interpretation of the development of Pasteur’s anthrax vaccine in nineteenth century France, Stokes (1997) advocated “Pasteur’s Quadrant,” or the domain of “use-inspired basic research.” In Stokes’ view, Pasteur’s research was use-inspired because it aimed to generate a solution to the anthrax problem, but basic because it led to scientific discoveries. Many have used Stokes’ work to argue that impacting practice demands “scaling up” or “disseminating” research-inspired interventions, similar to how Pasteur’s vaccine was developed in the lab and then diffused to farms.

Stokes’ writing provided significant inspiration for scholars in many fields, including engineering education (Smith, 2008). Yet as Shaffer and Squire (2006) argue, applying the idea of Pasteur’s Quadrant to educational research and practice is problematic to the extent it: (a) assumes a unidirectional model where research results affect practice but not the reverse, and (b) fails to challenge dominant educational practices. Additionally, they note that such models may presume a boundary between researchers and practitioners. In response to these shortcomings, these same writers use Latour’s alternate historical interpretation of Pasteur’s scientific work (Latour, 1988) to argue that research and practice should be viewed in even more integrated and cyclic terms.

As noted by Smith (2008), Stokes’ work also informed the “cycle of knowledge production and improvement of practice” model, attributed to RAND (Ball, 2003). It was later adapted for use by the U.S. National Science Foundation (NSF) for its Course, Curriculum, and Laboratory Improvement (CCLI) program, which supports improvements in undergraduate STEM (Science, Technology, Engineering and Mathematics) education (National Science Foundation, 2007). As indicated in Figure 1, this model proposes that novel educational research can challenge existing teaching and learning methods, thereby stimulating the development and evaluation of new educational innovations and assessment strategies. New research is generated in turn, and the cycle starts over. This cyclic framework also proposes that scaling-up can occur when new educational materials and teaching strategies are “first tested in limited environments and then implemented and adapted in diverse curricula and educational institutions” (National Science Foundation, 2007).

<table>
<thead>
<tr>
<th>Is research driven by a desire for fundamental knowledge or understanding?</th>
<th>Pure basic research</th>
<th>Use/need-inspired basic research (Pasteur’s Quadrant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Systematic yet particularistic research</td>
<td>Pure applied research</td>
</tr>
<tr>
<td>No</td>
<td>Is research driven by practical needs or uses?</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Stokes’ research quadrants (Stokes, 1997).

Figure 1. Cyclic model relating knowledge production and improvement of practice (National Science Foundation, 2007).
Research can also be related to domains other than educational practice. As noted above, Burkhardt and Schoenfield (2003) discuss how educational research might be linked to policymaking, but they do not describe specific mechanisms for achieving this outcome. Funding agencies in other parts of the world are also working to both recontextualize and bridge research and practice. “Evidence-based Policy and Practice,” for instance, is a current European Union (EU) initiative that funds “knowledge brokerage initiatives” to support “coherent arrangements for the accumulation, mediation and application of educational research” (European Commission, 2009). In addition to advocating engagement with policymakers and educational practitioners, this program also supports projects that can help align educational and training systems with current and future labor market needs. However, the current call for proposals does not provide an explicit framework for relating research to these other domains.

C. Relating Research and Practice in Engineering Education

Against the backdrop of changing national policy agendas, the field of engineering education largely originated with the practical concerns of engineering educators. In the early 2000s, and especially in the United States, calls were made to increase the quantity and quality of engineering education research, with an emphasis on impacting practice (Jesiek, Newswander, and Borrego, 2009). A growing body of evidence also reveals widespread support in the global engineering education community for continuing to nurture the connections between research and practice (Borrego, 2007; Jesiek, Newswander, and Borrego, 2009).

Referencing the work of Burkhardt and Schoenfeld (2003), Smith (2008) points to three specific mechanisms or models most often used to link research and practice in engineering education, namely: teachers reading and using research, summary or best-practice guides, and promoting faculty/staff development. Other specific bridging strategies proposed in recent years include: bringing new researchers into the field; working to identify generalizable results and knowledge transfer opportunities; promoting action research (Feldman and Minstrell, 2000) and evidence-based research; establishing engineering education centers at universities; organizing workshops to increase the level of scholarship and enhance the research skills of engineering educators; and publishing practice-oriented papers in outlets such as Advances in Engineering Education, Australasian Journal of Engineering Education, or Engineering Education: Journal of the Higher Education Academy Engineering Subject Centre (Borrego, 2007; Jesiek, Newswander, and Borrego, 2009).

Others have framed the research-practice relationship by using a more general developmental framework, where engineering educators might first embrace good engineering teaching and then move toward scholarship and ultimately engineering education research (Borrego et al., 2008). By scholarship, we mean the scholarship of teaching and learning, as defined by Boyer (1990) and Hutchings and Shulman (1999). Scholarship of teaching “is public and open to critique and evaluation, is in a form that others can build on, involves question-asking, inquiry and investigation, particularly about student learning” (Borrego et al., 2008, p. 155; Streveler, Borrego, and Smith, 2007). Frequently these exchanges occur at national and international engineering education conferences, but they may also happen at the campus level. Engineering education research has the characteristics of scholarship but creates potential for broader impact of results because it is also: (1) guided by a research question focusing on the “why” or “how” of learning or education more broadly; (2) is guided by a learning, pedagogical or social theory and interprets results in light of that theory; and (3) pays careful attention to study design and methods to stand up to scrutiny (Borrego et al., 2008; Streveler, Borrego, and Smith, 2007). Although delineation is necessary to aid readers, we emphasize that we and other authors who define these terms place them on a fluid continuum that downplays rather than reinforces rigid distinctions.

III. Methods

A. Setting and Participants

The setting for this study is Advancing the Global Capacity for Engineering Education Research (AGCEER):

AGCEER is a joint initiative by the European Journal of Engineering Education, published by the Société Européenne pour la Formation des Ingénieurs (SEFI), and the Journal of Engineering Education, published by the American Society for Engineering Education. The goal is to significantly advance the global capacity for engineering education research through moderated interactive sessions offered in a series of international engineering education conferences between July 2007 and December 2008. The sessions address fundamental questions facing the development of a global community of scholars and practitioners in engineering education research (Lohmann and de Graaff, 2008, p. 1).

Table 2 lists the conferences at which the AGCEER sessions were held, a summary of participant characteristics, and the abbreviation for each session used throughout the rest of this article. Sessions varied in length from approximately 45 minutes to two hours. Each session featured one to four invited guest speakers who commented for 10–20 minutes on a topic related to building global capacity for engineering education research. In groups of four to six, participants then discussed questions related to the nature of engineering education research, important research questions or areas, and types of available support. Questions were updated for each session, including improving their clarity, based on the outcomes of the previous sessions. The questions asked at each session are listed in Table 3. European 1 participants self-selected groups to discuss only one of the questions; participants at all other sessions were asked to discuss all questions and report on as many as time allowed. European 3 was also an exception to this format; there, participants held a single discussion as one large group. In each case, one member of each group took notes on the group discussion and submitted them to session organizers.

AGCEER participants are typical engineering education conference attendees: staff/faculty interested in improving their teaching; staff/faculty presenting their scholarship of teaching and learning; engineering deans/heads of schools and heads of departments; researchers and other scholars who study engineering education; and industry/government employees or similar stakeholders in engineering education. In most cases (all but Hong Kong/China), AGCEER sessions were optional (held in parallel with other conference sessions), so there was some degree of self-selection beyond attending an engineering education professional...
The participants are representative of those who might attend an ERM (ASEE or AAEE) or EER-WG (SEFI) group meeting or technical session, most of whom conduct some type of scholarly work in engineering education themselves. While we are careful not to characterize the level of scholarship in particular countries or regions, we posit that AGCEER participants are generally representative of the group of stakeholders in engineering education research movements across the globe. While the length of the sessions necessarily restricted the depth of our data, we emphasize that its breadth (involving over 300 participants from 10 conferences on 6 continents) is unprecedented in international analyses of engineering education.

### B. Data Collection

Session organizers made audio recordings of the reporting portions and collected note pages from each group. Human subjects approval (Virginia Tech IRB #07-295) was secured to use these recordings and notes as data sources. Transcripts of AGCEER report back, AGCEER presentation slides, and general observations at other conference sessions also served as data sources.

<table>
<thead>
<tr>
<th>Conference Name, Date, Location</th>
<th>Conference Organizers</th>
<th>AGCEER Participants</th>
<th>Abbrev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st SEFI-IGIP Joint Annual Conference, 1-4 July 2007, Miskolc, Hungary</td>
<td>European Society for Engineering Education (SEFI), and International Society for Engineering Education (IGIP)</td>
<td>21 Participants (100% from Europe), 4 Speakers (Europe and U.S.), and 2 Journal Representatives</td>
<td>European 1</td>
</tr>
<tr>
<td>6th Global Colloquium on Engineering Education, 1-4 October 2007, Istanbul, Turkey</td>
<td>American Society for Engineering Education, Bo azici University, and the Turkish Engineering Deans Council</td>
<td>45 Participants (60% from U.S.), 2 Speakers (U.S. and Canada), and 2 Journal Representatives</td>
<td>Global Colloquium</td>
</tr>
<tr>
<td>1st International Forum on Engineering Higher Education, 8-10 November 2007, Hong Kong, China</td>
<td>Hong Kong Polytechnic University and Zhejiang University, China</td>
<td>37 Participants (86% from China, Hong Kong, Taiwan or Japan), 2 Speakers (Hong Kong and China), and 1 Journal Representative</td>
<td>Hong Kong/China</td>
</tr>
<tr>
<td>2007 Australasian Association for Engineering Education Conference, 9-12 December 2007, Melbourne, Australia</td>
<td>Australasian Association for Engineering Education (AAEE)</td>
<td>21 Participants (95% from Australia or New Zealand), 2 Speakers (U.S. and Australia), and 1 Journal Representative</td>
<td>Australasia</td>
</tr>
<tr>
<td>2008 American Society for Engineering Education Annual Conference and Exposition, 22-25 June 2008, Pittsburgh, USA</td>
<td>American Society for Engineering Education (ASEE)</td>
<td>53 Participants (85% from U.S.), 2 Speakers (Australia and U.S.), and 2 Journal Representatives</td>
<td>U.S.</td>
</tr>
<tr>
<td>2008 SEFI Annual Conference, 1-4 July 2008, Aalborg, Denmark</td>
<td>European Society for Engineering Education (SEFI)</td>
<td>29 Participants (83% from Europe), 1 Speaker (U.S.), and 2 Journal Representatives</td>
<td>European 2</td>
</tr>
<tr>
<td>37th International IGIP Symposium, 7-10 September 2008, Moscow, Russia</td>
<td>International Society for Engineering Education (IGIP)</td>
<td>9 Participants (100% from Europe), 1 Speaker (Europe), and 1 Journal Representative</td>
<td>European 3</td>
</tr>
<tr>
<td>COBENGE 2008, 8-11 September 2008, São Paulo, Brazil</td>
<td>Brazilian Association for the Teaching of Engineering</td>
<td>42 Participants (100% from Brazil), 1 Speaker (U.S.), and 1 Journal Representative</td>
<td>Brazil</td>
</tr>
<tr>
<td>7th Global Colloquium on Engineering Education, 20-24 October 2008, Cape Town, South Africa</td>
<td>American Society for Engineering Education and the University of Cape Town</td>
<td>13 Participants (69% from Africa), 1 Speaker (South Africa), and 1 Journal Representative</td>
<td>South Africa</td>
</tr>
<tr>
<td>38th Indian Society for Technical Education National Annual Convention, 13-15 December 2008, Bhubaneswar, India</td>
<td>Indian Society for Technical Education (ISTE)</td>
<td>23 Participants (100% from India), 1 Speaker (India), and 1 Journal Representative</td>
<td>India</td>
</tr>
</tbody>
</table>

AGCEER = Advancing Global Capacity for Engineering Education Research

Table 2. Conference sessions and participants.
C. Data Analysis

We applied thematic analysis (Boyatzis, 1998) to categorize and understand the textual data of report back transcripts and note pages. The open source TAMS Analyzer software application was used to manage the coding and analysis of all data (Weinstein, 2006). According to an open coding procedure (Strauss and Corbin, 1998), codes (the columns in Table 4) 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 checked her work. All three authors worked together to confirm the findings by triangulating them with related research and the literature (Patton, 2002).

This paper is focused on research-practice relationships; other findings (related to specific research areas and interdisciplinary collaboration) are reported elsewhere (Borrego, Beddoes, and Jesiek, 2009). Preliminary results based on data from the first four AGCEER sessions were also published previously (Borrego, Jesiek, and Beddoes, 2008). The final coding scheme appears in Table 4. Because AGCEER discussions varied widely in content and scope, the authors did not systematically examine how specific session questions were correlated with specific discussion topics or themes. However, these relationships were used on an as-needed basis.

### Table 3. AGCEER session questions.

<table>
<thead>
<tr>
<th>Questions*</th>
<th>Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What makes engineering education research different from other forms of innovation in engineering education? (Is the problems studied? The methods and approach employed? The knowledge base needed? The qualifications of the researchers? …)</td>
<td>European 1 Global Colloquium Hong Kong/China Australasia</td>
</tr>
<tr>
<td>2. What kind of expertise is needed to conduct engineering education research in the various disciplines of engineering (e.g., civil, electrical)?</td>
<td>U.S. European 2 European 3 Brazil South Africa India</td>
</tr>
<tr>
<td>3. What structures and mechanisms already encourage and support engineering education researchers, and which others need to be created and implemented? (For example, academic departments, research centers, funding, research journals, professional societies, research conferences, …?)</td>
<td>European 1 Global Colloquium Hong Kong/China Australasia</td>
</tr>
<tr>
<td>4. What are the important research topics or areas for engineering education research to investigate in the future?</td>
<td>U.S. European 2 European 3 Brazil South Africa India</td>
</tr>
</tbody>
</table>

*One additional question specific to the local professional society and asked only at the Australasia session, was excluded from this analysis.

### Table 4. Relating research to practice, policy, and industry.

<table>
<thead>
<tr>
<th>Questions to educational practice</th>
<th>Questions to policy, including policy research</th>
<th>Questions to industry, profession</th>
</tr>
</thead>
<tbody>
<tr>
<td>European 1</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Global Colloquium</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hong Kong/China</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Australasia</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>U.S.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>European 2</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>European 3</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Brazil</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

*Participants in the Brazil session discussed the importance of faculty/staff development, but were not more explicit about relating research and practice.
basis to help contextualize the data. In addition, it is inappropriate to provide frequency counts for each session given the qualitative nature of this data. Further, frequencies would be artificially high for groups that listed issues on their note pages and mentioned them in their report back.

A major limitation of this data is lack of depth due to time constraints on the sessions (most of which were under two hours). We were careful not to over-interpret participant responses. One implication for this analysis is that if a particular issue was not mentioned at a specific AGCEER session, we cannot conclude that it is not a concern in that region; we can only report that it was not mentioned in that session. Although this data does not provide enough detail to describe subtle variations across countries and regions, the frequency with which many similar issues were mentioned across the sessions is encouraging for the future of the international engineering education scholarly community.

IV. RESULTS

We expected to find significant differences across AGCEER sessions, but instead observed generally high levels of agreement and consensus. Consequently, the results are presented as one coherent description, using direct quotes from all sessions and highlighting critical differences when and where they arise.

A. Relating Research to Educational Practice

One major theme that surfaced at many AGCEER discussions was captured by a European 3 participant, who asked: “What’s the objective of the research? Is it getting to know why, or is it getting to know how to improve education?” Groups at the South Africa and European 2 sessions noted similar challenges related to identifying audiences for projects and publications, including researchers and/or educators. One Global Colloquium group characterized engineering education research as “stratified from local to rigorous,” and they expressed concerns about the field being overly focused on the latter. Still other Colloquium participants warned that a lack of strong researcher-practitioner ties could come with a “danger of elitism.”

Despite such concerns, we observed frequent discussion and widespread consensus among AGCEER participants about the importance of relating engineering education research to the practice of engineering teaching, as indicated in Table 4. However, closer analysis also reveals some notable variations, both within and across sessions, about how participants described research-practice relationships and how they might best be advanced.

1) Stakeholders: As we report elsewhere, AGCEER participants consistently expressed a desire for interdisciplinary collaboration through teamwork (Borrego, Beddoes, and Jesiek, 2009). That is, they advocated conducting research via teamwork between engineers and social scientists, including educational researchers.

Educational practitioners were also frequently identified as important stakeholders in these collaborative efforts because of both their teaching experience and knowledge of engineering subjects and content. As one South Africa participant explained: “Obviously the engineers are more familiar with the discipline subject, the thinking processes required for it, the difficult material and such areas where students have problems.” At other sessions, participants noted that engineering education research demands “teaching experience” (Brazil) and “a very strong connection with engineering education practice in that specific discipline” (U.S.). A European 2 group similarly noted the importance of having “researchers (at least part of them) [who] are also educators,” while a European 3 participant added that the relevance of research might be enhanced if “we have not to think in terms of doing research by researchers but doing research by teachers.” In light of these observations, we propose that one continuing challenge for the field involves supporting both multidisciplinary collaborations and the movement of individual educators along a path toward scholarly teaching and perhaps also educational research (Streveler, 2007).

2) Directionality: As noted in the literature review, research and practice can be viewed in directional terms, such as by asking how research can inform practice, or vice-versa. We observed three kinds of directionality in the AGCEER discussions. The first involved advocating the dissemination or diffusion of research findings to engineering teachers. Representative statements included: “transfer research results to engineering education practice” (U.S.), “the knowledge does need to get disseminated” (Australia), and “transferring of pure or fundamental foundational knowledge into applied courses such that there’s no irrelevance there” (European 2). One Hong Kong/China group offered an even more systematic formulation by defining “innovation in engineering education” as “implementation of practically useful methods and techniques based on the outcomes of education research.”

While such remarks may appear rather straightforward, Shaffer and Squire’s (2006) work reminds us that these comments may carry problematic assumptions about research driving practice in a unidirectional manner.

A second kind of directionality was implied when AGCEER participants posited that researchers should consider questions about the applicability and relevance of their studies at the outset. After explaining the types of expertise that engineering instructors bring to engineering education research, a South Africa group emphasized an important benefit: “And coming from a practical viewpoint the research will feed back directly into the teaching process.” One European 3 participant explained: “It’s very nice if we know that we have scientific knowledge about so and so, but if it has no relevance for improving education then I think from an engineering education perspective it’s useless.” The group went on to recommend including engineering instructors in a “kind of participating research” with “the teacher as a researcher.”

In the Hong Kong/China session, participants more specifically explained that there was a shift underway in China from theory to application-oriented research. “In China, most of the scholars focus on the theory study, since the government encourages us to do so. Now, in order to enhance the level of application, we pay more attention to the application study.” The need to keep practice in mind when conducting research also came up in European 2, with one group arguing that if teachers are the intended audience for a research project, then the research questions and arguments should be tailored to them rather than other researchers. Many of these comments suggest a reversed directionality, with research significantly driven by practical needs and considerations.

Groups at two AGCEER sessions advocated a third kind of directionality, namely a “cyclic relationship” between research and teaching practice. More specifically, Global Colloquium participants noted the importance of “support[ing] researchers on the
journey in practice and research cycle," while Australasian participants explained:

You might have a clear cut question to do research … which leads to innovation, which leads to implementation, which leads to reflection, and then perhaps an implementation [in/and] practice. It’s more of … a cycle that has rigor and research and reflection attached and research and innovation might be part of that.

These characterizations suggest that more nuanced and multifaceted understandings of the research-practice relationship, such as the cyclic framework adopted by the U.S. NSF, are tentatively being taken up in the engineering education community. As we discuss in more detail, this kind of framing may also help reduce research-practice tensions by providing bidirectional modes of interaction. However, such approaches may also demand continuing efforts to both identify appropriate roles for relevant stakeholders and develop specific mechanisms and strategies for relating research and practice.

3) Mechanisms and Strategies: AGCEER participants discussed many specific mechanisms and strategies for relating research and practice, as summarized in Table 5.

As previously noted, some groups advocated disseminating research findings to specific target audiences, including engineering teachers. A European 1 group saw value in showcasing quality educational research, including examples of how it can improve practice. On the other hand, a European 2 group noted challenges associated with presenting findings to different audiences, since researchers and teachers “may not be convinced by the same arguments.”

More common were discussions about building connections and community, both among researchers and between researchers and instructors. Specific strategies for building community included: recruiting and supporting scholarly teachers and researchers, organizing conferences and workshops, and publishing results with practitioner audiences in mind. Australasia participants were uniquely interested in using online mechanisms to establish and share relevant literature and research findings. They went on to discuss developing Web resources such as a bibliography accessible to novices, statistics tutorials, examples of good practices, case studies, and links to other pertinent Web sites. Participants at European 3, on the other hand, more directly proposed turning engineering teachers

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Table 5. Mechanisms and strategies for relating research and practice.

<table>
<thead>
<tr>
<th>Transfer Research into Practice</th>
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<tbody>
<tr>
<td>• Disseminate results to teachers; Apply research results to teaching (European 1, Global Colloquium, Hong Kong/China, U.S., European 2, South Africa)</td>
</tr>
<tr>
<td>• Share examples/cases of how research can inform teaching (European 1)</td>
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<tr>
<th>Encourage Scholarly Teaching and Educational Research</th>
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<tbody>
<tr>
<td>• Promote scholarship of teaching and learning among faculty (Global Colloquium, U.S., South Africa)</td>
</tr>
<tr>
<td>• Provide engineering teachers with research skills, tools, examples (Australasia, European 3)</td>
</tr>
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<table>
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<tr>
<th>Build Infrastructures to Support Scholarly Teaching, Educational Research</th>
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<tbody>
<tr>
<td>• Teacher training or faculty/staff/professional development (European 1, U.S., European 2, European 3, Brazil)</td>
</tr>
<tr>
<td>• Provide research and/or teacher training to engineering graduate students (Hong Kong/China, Brazil)</td>
</tr>
<tr>
<td>• Establish teaching and learning centers in universities (Global Colloquium, Hong Kong/China)</td>
</tr>
<tr>
<td>• Develop an online bibliography for engineering education research (Australasia)</td>
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<tr>
<td>• Organize conferences and workshops (European 1, Australasia)</td>
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<table>
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<tr>
<th>Enhance Recognition of Effective Teaching</th>
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<tr>
<td>• Improve recognition of scholarly teaching in promotion and tenure process (Global Colloquium, Hong Kong/China)</td>
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<tr>
<td>• Establish more and better faculty teaching awards and fellowships (Global Colloquium)</td>
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<tr>
<th>Bring Education into Traditional Engineering Disciplines</th>
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<tr>
<td>• Include education-related content in disciplinary journals, conferences (Global Colloquium, Hong Kong/China)</td>
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</table>
into educational researchers. They explained that this would entail giving engineering instructors the right knowledge, methods, and tools so they could research their own questions and “solve their own problems.”

There was also widespread interest in providing formal training for instructors (“teacher training” or “faculty/staff/professional development”). General mention of this theme came from many sessions, with participants at the U.S. session elaborating:

… a research area that needs some definite work is faculty development. With the professors that get to be professors with no pedagogical training at all, what sort of impact can that have in engineering and the university in general to have greater faculty development?

Others spoke of the value of teaching educational/learning theories to graduate students, who represent the next generation of faculty. Infrastructures such as teaching programs and centers for teaching and learning were advocated in the Hong Kong/China, Global Colloquium, and European 1 sessions. Global Colloquium participants added that such initiatives should focus on training both new and experienced professors.

It is worth emphasizing that faculty/staff development was itself identified as an important research area at five of ten AGCEER sessions, as indicated in Table 5. In addition, at six of ten AGCEER sessions (Europe 1, U.S., Europe 2, Europe 3, Brazil, and South Africa), participants more generally indicated the desirability of conducting research on the beliefs, perspectives, and/or behaviors of engineering faculty/staff. Given these findings, there may be great potential to develop enhanced understandings of research-practice cycles, including by providing more opportunities for faculty/staff development and conducting research on such interventions.

To bolster recognition of scholarly and research-driven teaching some AGCEER participants at the Global Colloquium called for improved recognition of teaching effectiveness in promotion and tenure, while others desired more and better teaching awards or fellowships for engineering faculty. Groups at Hong Kong/China and Global Colloquium advocated working through traditional engineering professional societies and their associated conferences, including to disseminate research findings.

B. Relating Research to Policy

Some AGCEER participants recognized that engineering education research can and should have impacts that extend well beyond the domain of teaching practice. In European 1, for example, a group noted that events like conferences could “support exchanges of ideas beyond actual classroom practice, beyond actual teaching, so looking at engineering education on a much broader scale.” In three of the sessions (European 1, Hong Kong, European 2), participants more specifically discussed relating research and policy. For example, a group at European 1 expressed concerns that “people may or may not be making [policy] decisions based on research studies,” while some Hong Kong/China participants advocated that educational policy changes should be “informed by research.” One suggestion, from a group at European 2, would be to “embed the value of engineering education research in the minds of policymakers,” including by showing how research can provide a sound background for educational innovations.

A second way in which policy entered the discussion was through mention of “engineering education policy” and “engineering education systems” as important research areas by a group at European 2. On one hand, these comments appear synergistic with the kinds of research-driven policy and practice initiatives that seem to be gaining traction in the EU and elsewhere. Yet as the European 2 participants acknowledged, working in these areas would also likely demand the involvement of researchers with “totally different competencies,” especially as compared to “pedagogical research.”

C. Relating Research to Industry and the Engineering Profession

Our data also reveal interest in relating engineering education research to industry and the engineering profession. A European 2 group identified “relation to industry” as an important research area, while India participants noted the value of “developing strategies for bridging the gap between industry and (academic) engineering institution(s).”

More specific research topics discussed at AGCEER sessions included university-industry alignment, or “making sure that we understand what it is that industry wants and expects with engineers of the future in this global market” (U.S.). However, some European 2 participants identified continuing engineering education and “upskilling” as important research areas. As one group explained: “In the U.K. particularly … we’re concerned with the effectiveness of workplace delivery of engineering teaching, of upskilling the workforce.” They went on to note the value of conducting longitudinal studies that followed students through higher education and into professional careers. One European 3 attendee added that researchers should look at the “sustainability of knowledge throughout the professional career,” and a Brazil group emphasized the importance of both “engineering markets” and bringing the realities of industry practice into engineering courses.

Some European 2 participants also discussed the need for industry expertise among engineering education researchers, including “firsthand experience of industry” and the “ability to reach out to industry.” One U.S. group added that researchers should be willing to partner and work with industry. Yet specific strategies for relating research to industry and the engineering profession were not articulated. One Global Colloquium group explained that it was important to “get industry involved” to help support and sustain engineering education research, but they stopped short of identifying specific mechanisms to support this objective. Questions remain, however, about whether a lack of connections between engineering education research and industry reflect the field’s more general tendency toward “academic professionalization,” with “pure” academic research privileged over the messy realities of actual engineering practice.

D. Relating Research, Globally

Explicit discussions about how engineering education research might be related to practice, policy, and/or industry across countries or regions were scarce, at best. In fact, a more general effort by organizers to form a discussion group on “enablers and barriers to international collaboration” at the European 1 session failed because of a lack of interest among attendees.

Nonetheless, AGCEER participants did discuss issues and challenges with likely implications for relating research and
practice across both local and national boundaries. One European 2 group emphasized that Europe alone has more than 30 different national educational systems. They added that many research results are published in a wide variety of national languages. Another group at the same session pointed to differences between individual institutions, including different emphases on research and/or teaching. Yet another European 2 group noted inter-university competition as a concern: “university management … might want to hinder publishing openly all educational development research because that is directly linked to core competencies of a university.”

Other relevant local and regional variations observed at AGCEER sessions include: a preference for top-down change led by university administrators in the Hong Kong/China context (Borrego, Jesiek, and Beddoes, 2008); recognition of unique constraints and opportunities posed by the Bologna Declaration and policy process in the EU; and concerns about how excessive educational regulations may inhibit teaching and learning innovations in Brazil. An Australasia group pointed to still another relevant concern: “accreditation panels … are not necessarily recognizing the importance of innovation.” In each case, contextually appropriate models and strategies will likely be required to enhance the effective linking of research to educational practice, policy, and industry.

V. DISCUSSION AND RECOMMENDATIONS

Across AGCEER sessions, comments about relating research to educational practice surfaced repeatedly. However, we observed little discussion about the implications of adopting different understandings of the research-practice relationships (e.g., dissemination versus cyclic). Further, these different understandings were rarely explicitly related to: (a) the larger goals and objectives of engineering education research, (b) different stakeholder populations, and (c) specific mechanisms or strategies for relating research and practice. Conversations about relating research to policy and industry were also underdeveloped. To promote continued discussion and study of these important themes, we close by proposing three new ways to think about how research can be related to practice, profession, and industry across diverse local and global contexts.

First, we take some inspiration from Lohmann and de Graaff’s research-development metaphor (2008), as well as the AGCEER groups that described the research-practice relationship in cyclic terms. Yet as noted, even these types of framing may be problematic to the extent they oversimplify the research-practice relationship, privilege research over practice, and/or fail to challenge dominant educational practices. In response to such shortcomings, we sympathize with Burkhardt and Schoenfeld’s description of a productive “dialectic” between research and practice (2003). This term implies a more balanced and integrative relationship, where research-practice interactions promote the emergence of new synthesis over time.

Second, we propose enriching this cyclic model by adopting Latour’s terms translation and enrollment (1988), as illustrated in Figure 2. The term translation emphasizes that novel practices and interventions are rarely diffused or scaled up in static form, but are rather received, negotiated, and perhaps even rejected by stakeholders who are both unruly and diverse. Latour’s (1988) concept of enrollment on the other hand, reminds us that change almost always demands that leading actors convince other stakeholders and groups to adopt specific roles and rally around particular projects and visions. These ideas suggest, for example, that engineering instructors should be enrolled as equal and active partners in engineering education research. This can help ensure that studies are relevant, results are translated and disseminated in an accessible manner, and educators are given opportunities to learn how to conduct educational research. Research should also be framed so that engineering teachers feel invited into the field, rather than excluded by an elite class of researchers (Jesiek, Newsander, and Borrego, 2009). Many similar insights follow from a diffusion of innovations (Rogers, 1995, 2003) view of how novel interventions and research findings are disseminated in engineering education.

The concepts of translation and enrollment are also more broadly applicable. Research results with policy implications, for example, should be translated in ways that enhance their reception
and cultivate open, bidirectional dialog with policy analysts and policymakers. More specifically, pressing concerns about teaching practices or new educational policies can help drive the development of new research questions, even as prior findings should stimulate research-informed educational interventions and policy reforms. Opportunities to perform systematic research in related areas—such as staff/faculty development, STEM policy, and industry needs and practices—should also be seized, thereby broadening and enriching the scope of engineering education research. To increase impact and chances of success, policymakers and policy researchers should be actively enrolled in such initiatives.

Third and finally, we conclude that identifying similarities across countries and regions represents another important step toward building an effective global research community, pushing the frontiers of research, and avoiding isolated, local studies that “reinvent the wheel.” Yet it is essential to acknowledge and negotiate contextual diversity. Researchers should look for opportunities to translate research questions, theories, methods, and findings so they are readable and relevant across national and institutional boundaries. This in turn demands robust understandings of local differences in culture, educational systems, and desired graduate attributes. Examples of such translations include: how do local differences in culture and education influence student learning styles, team dynamics, the implementation of problem-based learning, or understandings of sustainability? What student attributes and skills are desired across countries and regions? What research efforts and findings related to curricular alignment, assessment, and accreditation are sharable across borders?

Internationalization trends in higher education can be leveraged to begin addressing such questions. Many universities are now encouraging global awareness, education, and citizenship among students and staff, including through cross-national research collaborations, partnerships with foreign institutions, study abroad programs, recruitment of international students and teaching staff, distance education initiatives, and international conferences and workshops (Knight, 2005; Stromquist, 2007). Many prominent engineering leaders and stakeholders are also calling on engineering educators to train “global engineers” who can practice effectively in a diverse and globalized world (Grandin and Hirleman, 2009), while others have acknowledged the international character of much engineering teaching and research (National Research Council, 2007, Ch. 3; Bremer, 2008). The field’s advocates and stakeholders should promote complimentary objectives, such as cross-national research partnerships, exchanges of students and teaching staff, and international workshops and summits.

Yet as geographically diffuse researchers with similar interests begin to collaborate, they may encounter challenging differences in disciplinary paradigms, terminology, publishing traditions, career pathways, project management strategies, human subjects protections, and power dynamics (Hakala, 1998; National Research Council, 2008). Nonetheless, it is imperative that leading stakeholders proactively leverage current internationalization trends, while strategically relating engineering education research to practice, policy, and industry across local and global boundaries. Failure to do so may thwart future collaboration and community building, thereby impairing the field’s development. In fact, engineering education researchers should heed the lessons from other social science fields that developed regional schools of thought, or underwent academic professionalization such that research appears scarcely related to empirical realities. The strategies and frameworks presented above are intended to prevent such splintering and promote international synergy and collaboration. In summary, we urge readers to think globally about the development of engineering education as a research field, while acting locally to enroll new actors and perform context-sensitive translations.

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