Guest Editorial

Conducting Rigorous Research in Engineering Education

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ENGINEERING EDUCATION BECOMES A DISCIPLINE

The field of engineering education is in the process of reinventing itself and the January 2005 special issue of the *Journal of Engineering Education* was a milestone event in this transition [1, 2]. The four most recent guest editorials have documented this reinvention and have suggested shifts that are needed to establish engineering education as a serious and rigorous research-based discipline [3–6]. Gabriele suggested that research in engineering education move from curriculum reform to conducting fundamental research in how students learn engineering and he stressed that this shift is needed now to move the field forward [4]. Haghighi emphasized that "engineering education research is the most effective avenue through which we can address overarching and grand questions" [5, p. 351]. He also encouraged the broader community of engineering educators to shift from "teaching to learning." [5, p. 352]. Currently, engineering education research still tends to focus very heavily on teaching and curriculum development rather than research.

Given this backdrop, the question now becomes "How does one prepare engineering educators to conduct the kind of research that is now being called for?" Specifically, we ask, "What can be done to prepare engineering education researchers to shift their focus from teaching and curriculum development to exploring fundamental questions about engineering learning?" In an attempt to begin to answer this question, we share some insights that have been gained from working with engineering faculty in the NSF-sponsored project, "Conducting Rigorous Research in Engineering Education: Creating a Community of Practice," hereafter called RREE [7].

WHAT IS RIGOROUS RESEARCH IN ENGINEERING EDUCATION?

The purpose of the RREE project is to prepare faculty to conduct rigorous research in engineering education. Our first task then is to define "rigorous" research in this context. We have chosen to define rigorous research in engineering education by using the guidelines provided by the National Research Council (NRC) in the work, *Scientific Research in Education* [8]. According to this NRC report, scientific or rigorous research in education (including engineering education) should:

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

These guidelines parallel the criteria for rigorous research in engineering and science and thus are familiar to engineering educators. However, our work with engineering faculty has suggested that engineering faculty tend to think of education questions in a very different light. Specifically, we have found that the majority of engineering education questions that faculty brought to the RREE reflected three qualities:

- Their purpose was to improve teaching in an individual researcher's classroom. As such, they focused on very context-specific questions within the classroom and could be classified as exhibiting what Boyer called the "Scholarship of Teaching and Learning" [9]. While providing one's students with the very best teaching is admirable, and the place most college professors enter the field of educational research [10], the very specific nature of these studies can make their results difficult to replicate and generalize.
- They tended to focus on assessment questions that would help ascertain if one teaching method had a more positive impact on student learning than another. Assessment questions, which answer questions about what students are learning, are important to answer. However, they often cannot help answer the "why" or "how" questions about engineering learning [11] that the engineering education community is now being asked to answer [4].
- They were often not linked to learning, social, psychological, or pedagogical theory. Even in cases where new teaching methods which were more "active" were being designed and assessed, theory was not used to explain the study's findings. Without an explicit, well-articulated tie to the specifics of a theory, it is difficult to generalize across studies and the opportunity is lost to build theory, rather than just be informed by it. We agree that engineering education research needs to be in Pasteur's Quadrant [12], that is, it needs to build theory *and* inform practice.

The crux of the matter then is how to move faculty from conducting context-specific assessment studies to conducting studies

that are scientific or rigorous. The RREE Executive Committee [13], a multidisciplinary group composed of members of the American Society for Engineering Education (ASEE) [14], the American Educational Research Society (AERA) Professions Education Division [15], and the Professional and Organizational Development Network in Higher Education (POD) [16], tackled this problem when revising RREE for 2005. In addition to looking at what skills and knowledge that engineering faculty needed to conduct rigorous engineering education research, the RREE Executive Committee also very explicitly addressed *paradigm shifts* that were needed.

The RREE Executive Committee asked, "What kinds of paradigm shifts do engineering faculty, who have been trained to conduct rigorous *engineering* research, need to make to be able to conduct rigorous *engineering education* research?" In response to this charge we posited that comparisons should be made to help faculty understand the new paradigm [17] and we created exercises that gave faculty the opportunity to compare and contrast:

- engineering research with education research;
- assessment questions with research questions; and
- questions which focused on teaching and learning in their classroom (which we called the scholarship of teaching and learning) with questions that can answer more fundamental questions about how students learn engineering (which we called rigorous research in engineering education).

These were incorporated into the 2005 RREE and were well-received by the participants, although some faculty struggled to assimilate them into their engineering education research paradigm [17].

A New Paradigm for a New Discipline

What have we learned about how to prepare engineering faculty to conduct rigorous research in engineering education? We offer these recommendations for those wishing to engage in rigorous research in engineering education.

- The *purpose* of engineering education research needs to extend beyond an interest in improving an individual's teaching, or developing a specific curriculum. In order to begin to answer fundamental questions about how students learn engineering, engineering education research must take a broader, "big picture" view, which may well include studies conducted outside of the classroom.
- In order to increase significance and generalizability of engineering education research, the work must be tied to the appropriate educational, psychological, or sociological *theory*. Faculty who wish to engage in rigorous research in engineering education need to become familiar with this literature or, better yet, partner with psychologists, education researchers, or other social scientists, who can provide guidance on which conceptual framework might be most appropriate for the question being asked. When true collaborations between engineering faculty and learning and social scientist are formed, research in engineering education can *contribute* to learning theory, not only be informed by it. This idea is reinforced by Fensham, who states that any new research field must participate in theoretical and conceptual development [18].
- Faculty should know that the methods of educational research are often different from the *methods* of engineering research. As Wankat et al. state, "…students are far more difficult to categorize than I-beams or transistors…" [19, p. 227], and thus engineering methods will not always work when answering educational questions. Faculty should get guidance on the appropriate measures to use to answer a particular question.

We are encouraged by the enthusiastic response of engineering faculty and graduate students to engage in engineering education research, and are hopeful that the work will provide deep insights about engineering education practice as well as contribute to the fundamental body of knowledge.

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