Guest Editorial
Continuing to Build Engineering Education Research Capabilities

THE engineering education research community has progressed considerably since I attended my first Frontiers in Education (FIE) Conference in 1981. The FIE conference was started by the IEEE Education Society in 1971. The Educational Research and Methods (ERM) Division of the American Society for Engineering Education (ASEE) joined as a co-sponsor in 1973, and the IEEE Computer Society joined as a co-sponsor in 1995. If you are interested in the details, Jones has provided excellent summaries of the history of FIE [1], [2], and Budny [3] keeps the FIE website up to date.

The FIE conference has helped engineering faculty become more scholarly teachers. Becoming a scholarly teacher means being familiar with the best practices in engineering education, reading engineering education literature and engaging in periodic conversations about teaching and learning with colleagues, and conducting systematic assessment of their students' learning. The IEEE Education Society has provided extraordinary leadership in engineering education and is now well positioned to play a significant role in preparing engineering education researchers.

Recent editorials in the *Journal of Engineering Education* [4], [5] argue for increasing our emphasis on engineering education research beyond the small and dedicated members of the engineering education research community who have faithfully participated in the Frontiers in Education conferences. Authors of the National Academy of Engineering study *Educating the Engineer of 2020* [6] recommend the following:

> *Colleges and universities should endorse research in engineering education as a valued and rewarded activity for engineering faculty and should develop new standards for faculty qualifications.*

Three universities (Purdue, Virginia Tech, and Utah State) have started engineering education programs in their colleges of engineering, and several other universities provide opportunities for graduate students to perform engineering education research in traditional engineering departments. National Science Foundation (NSF)-funded Centers for Learning and Teaching (CLT) [which include the Center for the Advancement of Engineering Education (CAEE); the Center for the Integration of Research, Teaching, and Learning (CIRTL); and the National Center for Engineering and Technology Education (NCETE)] are contributing to the engineering education research capacity building mission. Check out the CLTNet website for more details [7].

The NSF-funded Rigorous Research in Engineering Education: Creating a Community of Practice (RREE) project, led by the ASEE, Ruth Streveler at the Colorado School of Mines, and Karl Smith at the University of Minnesota, is contributing to building the engineering education research community. RREE provides funding for 20 engineering faculty to participate in a year-long research project that begins with a one-week workshop and provides mentoring throughout the year. A parallel project directed by Norman Fortenberry, Director of the Center for the Advancement of Scholarship on Engineering Education (CASEE) at the National Academy of Engineering, provides funding for ten teams of three engineering and education/social science faculty from Historically Black Colleges and Universities (HBCU) to participate in a RREE, week-long workshop. The project is in its second year and has provided approximately 100 faculty with knowledge, skills, and a community for conducting rigorous engineering education research. The RREE project brings together experts from three organizations: the ASEE Educational Research and Methods Division (ERM), the American Educational Research Association (AERA) Division I (Education in the Professions), and the Professional and Organizational Development Network (POD). The response to RREE has been fabulous. The first year, we had over 80 applicants for the 20 positions; and the second year, after refining the selection criteria, we had over 40 applicants.

Resources that may be helpful as you engage in this work, or if you are helping or guiding your colleagues to engage in the work, are a book by Heywood [8] and the Web portal for Annals of Research on Engineering Education (AREE) [9]. AREE's mission is to provide access to resources and to engage the engineering-education research community in a consensus-seeking conversation about the nature of high-quality engineering-education research. Participating journals, including the IEEE TRANSACTIONS ON EDUCATION, identify papers appropriate for inclusion. Article authors are invited to write an *Extended Summary* and respond to one or more *Reflective Essay* topics. The Reflective Essay topics include the following questions.

- *Research questions*: With which research question did you start? How did the research questions develop? What allowed you to see the opportunity for this research project? How did the questions change as you designed and implemented the research? Which were the final research questions you investigated? To whom is the question significant and why? *Methodology*: What methodology did you use? How did you choose your methodology? What other methodologies did you

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consider? What criteria did you use to choose among them? In what ways did the methodology change as you implemented your research?

- *Analysis of data*: How did you analyze your data? Why did you choose that approach? What other approaches did you consider? If your analysis was collaborative, how did that work? How did you work together (e.g., serially analyzed the data; all sat around a table and accomplished the analysis through discussion together)? What difficulties arose during the analysis? What surprised you?
- *Chain of reasoning*: Discuss your chain of reasoning in moving from data analysis to interpretation. How did you develop this argument? What was most difficult in making the research explicit and clear for the journal's readers? *Design for rigor*: In what ways did you design your study to be rigorous? Were you able to implement the design in such a way as to achieve the rigor you desired?
- *Replicability and generalizability*: In what ways is your study replicable? In what ways is your study generalizable? How amenable is your study to being repeated on different campuses, in different disciplines, across classrooms, etc.? What studies do you think need to be done now, in light of what you learned? *Lessons learned*: What are the most important things you learned about doing educational research while doing this project? If you had the chance to go back in time and accomplish your research again, what would you do differently?

Currently, there are over 40 articles available for public view [9].

In January 2003, the *Journal of Engineering Education* (JEE) repositioned itself as an archival journal for scholarly research in engineering education. The journal now provides a forum for reporting on research that meets the following criteria, such as those set forth by Diamond and Adam [10] and updated by Diamond [11]:

1) requires a high level of discipline-related expertise;
2) is conducted in a scholarly manner with clear goals, adequate preparation, and appropriate methodology;
3) has significance beyond the setting in which the research is conducted;
4) is innovative;
5) can be replicated or elaborated on;
6) is appropriately and effectively documented, including a thorough description of the research process and detailed summaries of the outcomes and their significance;
7) is judged to be meritorious and significant by a rigorous peer review process.

This list developed by Diamond is a good guide for faculty interested in preparing a paper for publication in any engineering education research journal and especially for JEE. Another perspective on rigorous research in education that is getting a great deal of media attention is the National Research Council (NRC) report *Scientific Research in Education* [12].

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

The overlap between these two lists is considerable. A couple of important features on the NRC list are 1) the importance and role of theory and 2) the line of reasoning. Together, they provide excellent guidance for planning, conducting, and reporting engineering education research.

Other professional communities are engaged in conversations about education research in their disciplines, and we can learn much from these discussions. Medicine has a long history of systematic study of medical education. The physics-education research community has progressed significantly with over 30 universities now having physics-education research programs in their physics departments. As physics-education researcher McDermott [13] observed, "Unless we are willing to apply the same rigorous standards of scholarship to issues related to learning and teaching that we regularly apply in more traditional research, the present situation in physics education is unlikely to change." I agree and encourage the engineering education community to embrace rigorous research in engineering education.

Boyer [14] challenged us in 1990 to consider broadening the definition of scholarship beyond the scholarship of discovery to include the scholarship of integration, application, and teaching. In a subsequent paper, Boyer encouraged all of us to make connections across these forms of scholarship by embracing the scholarship-of-engagement [15].

> *The scholarship of engagement means connecting the rich resources of the university to our most pressing social, civic and ethical problems, to our children, to our schools, to our teachers and to our cities* ....

Schön, who has written extensively on the reflective practitioner, argues that this new scholarship requires a new epistemology [16].

> *The new forms of scholarship advocated by Boyer and others lie much closer to practice. They proceed through design inquiry* .... *The epistemology appropriate to the new scholarship must make room for the practitioner's reflection in and on action. It must account for and legitimize not only the use of knowledge produced in the academy, but the practitioner's generation of actionable knowledge in the form of models or prototypes that can be carried over, by reflective transfer, to new practice situations. The new scholarship calls for an epistemology of reflective practice, which includes what Kurt Lewin described as action research.*

We have a great deal to think about and discuss as we consider embracing broader framing of scholarship and engaging in systematic engineering education research. The participation

and leadership of the electrical and computer engineering community is essential.

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