Strategies for Building Engineering Education Research Capabilities: Reflections on Three Past Practices, Exploring Current Practices, and Speculating on Future Practices

Dr. Elizabeth Cady, National Academies of Sciences, Engineering, and Medicine

Dr. Elizabeth T. Cady is a Senior Program Officer with the Board on Science Education (BOSE) in the Division of Behavioral and Social Sciences and Education (DBASSE) at the National Academies of Sciences, Engineering, and Medicine. She conducts studies, workshops, and other projects focused on equitable, inclusive, and effective STEM education at all levels. From 2006-2023 she worked in the National Academy of Engineering (NAE) Program Office working on projects focused on equitable and inclusive engineering education and related research at the precollege and higher education levels. She earned M.S. and Ph.D. degrees in Cognitive and Human Factors Psychology from Kansas State University and a B.A. in psychobiology and political science from Wheaton College in Massachusetts.

Russell Korte, The George Washington University

Russell Korte, PhD. studies the social, cultural, and professional systems in organizations and higher education, along with their effects on learning and performance. This work focuses on the professional education and socialization of engineering students, the work of practicing engineers, as well as the preparation of professionals for their future careers. Dr. Korte is an Associate Professor of Human and Organizational Learning at The George Washington University where he combines his practical experiences of work in education, business, and industry with his research and teaching in professional education, professional practice, and the social foundations of work. He has published on topics ranging from organizational socialization (onboarding), workplace learning, organization studies, social science, and philosophy. He also works on a variety of topics supporting his students' work on decision-making, the meaning of work, and social connectedness in school and the workplace. Korte received his Ph.D. in Work and Human Resource Education from the University of Minnesota.

Dr. Karl A Smith, University of Minnesota, Twin Cities

Emeritus Professor of Civil, Environmental, and Geo- Engineering, Morse-Alumni Distinguished University Teaching Professor at the University of Minnesota; and Emeritus Cooperative Learning Professor of Engineering Engineering Education at Purdue University

Building Engineering Education Research Capabilities: Reflections on three past practices, explorations of current practices, and speculation on future practices

Purpose

The growth of the engineering education research community in the past twenty years has been remarkable. Several factors have contributed to the growth, including many universities starting engineering education and discipline-based education research PhD granting programs, the increased emphasis on engineering education research at the Engineering Education and Centers Directorate at the National Science Foundation, and the increased interest among traditional discipline-based engineering faculty in adding engineering education research to their research portfolio.

This panel summarizes three programs for building engineering education research capabilities, engages participants in conversation about current efforts, and provides an opportunity to explore future approaches.

The panelists will summarize, discuss lessons learned, implications and future prospects for (1) the Annals of Research on Engineering Education (AREE), (2) the Engineering Education Research and Innovation Networking (EER&I) sessions, and (3) Research on Engineering Education for Practice (REEP). Here are more details on these projects:

Helping Build the Engineering Education Research Community: The Annals of Engineering Education Research (AREE)

Over twenty years ago momentum was building for the advancement and formalization of the engineering education research community. Evidence of the growth included, for example, (1) the National Science Foundation funded the Rigorous Research in Engineering Education (RREE) project, (2) the Journal of Engineering Education changed its focus to the research journal for engineering education, (3) the Engineering Education Research Colloquies (EERC) released the Research Agenda for the New Discipline of Engineering Education, (4) and engineering education PhD-granting departments were in the formation stage.

Discussions at ASEE conferences, such as the 2006 Main Plenary, *Advancing Scholarship in Engineering Education: Launching a Year of Dialogue*, and especially at the Center for the Advancement of Scholarship on Engineering Education (CASEE) at the National Academy of Engineering focused on ways to help catalyze the growth of the engineering education research community. The need and case for AREE emerged from these conversations.

In January 2003, the Journal of Engineering Education (JEE) repositioned itself as an archival journal for scholarly research in engineering education. The journal provided a forum for reporting on research that met specific criteria, such as those set forth by Diamond and Adam [1] and updated by Diamond [2]:

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. 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 conducting research in education is the National Research Council (NRC) report Scientific Research in Education [3].

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.

The overriding question facing the AREE developers and researchers (Norman Fortenberry, Karl Smith, Alisha Waller, Ann McKenna, Susan Donohue, Beth Cady, and Wendy Knapp) was, what can be done to help build the knowledge, skills, and habits of mind to conduct high-quality engineering education research?

AREE's mission was 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 [4] – [6]. Participating journals identified papers appropriate for inclusion. Article authors were invited to write an Extended Summary (structured abstract) and respond to one or more Reflective Essay topics.

It was recognized that since the reader may not have access to the original article, authors were asked to provide a structured summary by responding to the following guiding questions:

1. What is the context or background of the study? What are the most significant findings from other research studies which influenced your work?
2. What are the research questions you investigated? Why are they important to engineering education?
3. What theoretical frameworks did you use? Explain any theoretical concepts, such as self-efficacy, double consciousness, transformation learning, etc., which are critical to the research.
4. Discuss your methodology. How did you collect data to investigate your research question? From whom did you collect it? How did you analyze the data?
5. Discuss your major findings and/or conclusions. Outline your chain of reasoning from data analysis to findings. Are there other interpretations which could fit your data and analysis? Are there alternative interpretations which you ruled out?
6. Discuss any recommendations for engineering education. Indicate future research plans or additional questions raised by this research project.
7. Please acknowledge any support you received for the project.

Authors were asked to consider a series of guiding reflection questions which correspond to activities in the research process. Authors were asked to use these one or two questions as a basis for writing their essays and discussing the process of engineering education research. The reflective questions are as follows:

1. 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?
2. Theoretical frameworks: What theoretical frameworks did you use? How did you choose the theoretical framework? What other theoretical frameworks did you consider? What criteria did you use to choose among them?
3. Methodology: What methodology did you use? How did you choose your methodology? What other methodologies did you consider? What criteria did you use to choose among them? In what ways did the methodology change as you implemented your research?
4. 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?

5. 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? Are there other interpretations which could fit your data and analysis? Are there alternative interpretations which you ruled out?
6. 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?
7. Recommendations: Discuss any recommendations for engineering education. Indicate future research plans or additional questions raised by this research project.
8. 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?

Twelve journals participated in the AREE experiment, including Chemical Engineering Education, Computer Science Education, the European Journal of Engineering Education, IEEE Transactions on Education, the ACM Special Interest Group on Computer Science Education (SIGCSE) publication Inroads, International Journal of Engineering Education, the International Journal of Mechanical Eng. Education, the Journal of Chemical Education, the Journal of Engineering Education, and the Journal of Women and Minorities in Science and Engineering.

After going public in the Summer-Fall of 2005, 8 issues of AREE were published (Summer 2005, Fall 2005, Winter 2006, Summer 2006, Fall 2006, Winter 2007, Summer 2007, and Fall 2008). For the first issue of AREE, we invited the editors of the 11 participating journals to recommend articles and 9 of them responded. From the set of 48 articles (142 authors), we received summaries of 9 articles and 11 reflective essays in time for inclusion in the first issue. For the second issue (Fall 2005), there were 28 articles and 34 reflective essays. For the third issue of AREE (Winter 2006), there were 21 articles and 26 reflective essays. The fourth issue of AREE (Summer 2006) contained 17 articles and 22 reflective essays, and the fifth issue (Fall 2006) contained 15 articles and 20 essays. The last issue in Winter of 2007 contained 17 articles and 20 reflective essays.

AREE was particularly successful in garnering affirmation from the participating journals and getting participating authors to submit reflective essays. In addition, those who have used AREE have commented on its usefulness, effective presentation, and user-friendly functions. AREE also saw an increase in the number of registered users to 725 and had 445 authors who contributed.

The AREE project was funded by the National Science Foundation and various models for sponsorship or subscription were explored for sustaining the initiative; however, none were

successful. We think there are several aspects of the AREE approach that are relevant for continuing to grow and develop the engineering education research community.

Engineering Education Research and Innovation Networking (EER&I) Sessions

Beginning in 2008, Jack Lohmann (then Journal of Engineering Education editor in chief) Ruth Streveler, Karl Smith, and from 2015 Rocio Chavela Guerra organized and facilitated networking sessions to help connect and build the engineering education research and innovation community. These sessions were primarily held at ASEE annual conferences. Over the 12 years the networking session was held it brought together tens of folks at various stages in implementing and building engineering education research and innovation programs, and especially welcomed and helped connect newcomers.

The organizers conceived of the sessions primarily as an opportunity for participants to meet and interact and hence the majority of the 90-minute sessions was devoted to networking. Another principal feature of the sessions was a snapshot of the landscape of engineering education research (EER) programs. Participants were invited to submit a single slide describing their program and these were assembled into a slide show that ran at the opening of the session and during the networking portion.

Typical sessions included 20-30 minutes of updates from, for example (1) new programs, (2) EER projects, (3) National Academy of Engineering projects, and (4) EER journal editors.

The EER&I Networking Session materials are archived at Karl Smith's **Engineering Education Research and Innovation** website. Here are some highlights from the sessions:

1. The first networking session was held at the 2008 ASEE Global Colloquium on Engineering Education Cape Town, South Africa and the session was facilitated by Jack Lohmann, Karl Smith, and Ruth Streveler. Jack said, "we have to move the hallway conversations into the sessions" and we did.

2. The 2010 EER&I Networking Session at the ASEE Annual Conference included briefings from 16 engineering education research PhD programs.

3. The 2011 ASEE annual conference featured two milestones in the emergence of the engineering education research community:

    a. The Main Plenary organized by Jack Lohmann and Karl Smith and facilitated by Karl Smith, featured the engineering education research and development work of Michael Prince, Khairiyah Mohd Yusof, Jacquelyn Sullivan, Arnold Pears, David Darmofal, and Anna Dollar.

b. The Networking Session, titled *A Celebration of the Engineering Education Research Community*, included a brief report on the Rigorous Research in Engineering Education and the Collaboratory for Engineering Education Research (CLEERhub), and the National Research Council Discipline-Based Education Research study, and devoted 60 minutes to networking opportunities for the over 30 universities represented.

4. The annual EER&I networking sessions included descriptions of the expanding EER and DBER PhD programs, research centers, and many projects, including for example (1) National Research Council Discipline-Based Education Research consensus study, National Academy of Engineering Frontiers of Engineering Education conference, ASEE Virtual Community of Practice (VCP), and NSF I-Corps™ for Learning.

5. The annual EER&I networking session continued through 2019 and followed the same format of program slides, updates and networking. Here were the EER&I updates for the 2019 session (EER&I Networking Sesson Slides):

a. ASEE EECHA - Engineering Education Chairs and Heads Association – Cindy Finelli
b. EER&I Networking Session – Reflection on the first ten years – Karl Smith
c. Brief Reports
    i. National Academy of Engineering – Beth Cady
    ii. EER Impact Study - Audeen Fentiman
    iii. EER Departments & DBER Programs
        1. Hans van Oostrom – University of Florida
        2. Lance Perez – University of Nebraska Lincoln
        3. Monica Cox – The Ohio State University
        4. Jenni Case – Virginia Tech
        5. Audeen Fentiman – Purdue Engineering Education Online

The Covid-19 pandemic intervened and halted the EER&I Networking Session as did the desire of the organizers – Karl Smith, Ruth Streveler, and Rocio Chavela Guerra – to pass the torch.

The Engineering Education Community Resource maintained by Adam Carberry and Ken Yasuhara provides up-to-date information on most aspects of the community, e.g., graduate programs, conferences, employment opportunities, resources for researchers, and much more.

We suggest that the participants of this panel consider the potential opportunities and affordances of in-person networking sessions at engineering education conferences.

Research on Engineering Education for Practice (REEP)

Reasoning that an important outcome of engineering education is the preparation of students to practice engineering after graduation, there is growing interest in studying how engineering is

practiced [7], [8]; how engineering graduates transition into their jobs/careers [9] - [11]; and how both engineering faculty and employers can better facilitate the development of students into successful practicing engineers [8], [12]. This work has produced several important studies of engineering work, highlighting the complex, multi-disciplinary, and idiosyncratic nature of engineering work *in situ*, as well as the broader and diverse body of knowledge and skills learned and used in the engineering workplace.

Research on engineering practice can be sorted into two broad categories based on the unit of analysis: the work or the worker [13]. Studies of the work of engineering tend to focus on the practices, systems, and routines of the group, organization, and industry, taking a more traditional sociological, anthropological, or technical approach. Examples of research topics in this category include: cooperative learning, distributed teams, project work, socio-technical practices, organizational structures/context, professional and systems approaches, etc. Studies of the workers of engineering focus on the intellectual and interactional processes among people taking a more psychological and sociological approach. Examples of research topics in this category include: self-directed learning, professional identity, the development and professionalization of early-career engineers, mentoring, problem-solving, team membership, and so on [13].

As with other research agendas in engineering education, research on engineering education for practice (REEP) has used multi-disciplinary research questions, theories, and methods in pursuit of better understanding the perennial "gap" between school and work, and how to better bridge this gap [14], [15]. The multi-disciplinary perspectives are not only found in the research designs, but also in the array of researchers that often include disciplines outside of engineering, such as sociologists, psychologists, anthropologists, educators, and scholars of organization and management studies.

In addition to conducting numerous studies of engineering practice, Russ Korte and others, have been studying the philosophical foundations of research and practice, and the preparation of researchers to conduct social science research in education and professional practice. He has argued for the importance of this area of research, summarized some of the previous research in this area, and suggested opportunities for expanding the range of future research in engineering education and practice–especially beyond the narrow technical perspectives that dominate higher education in STEMM disciplines.

Learning objectives

Participants in this special session will:

1. Enhance their familiarity with past approaches to building engineering education research capabilities

2. Identify current practices, and highlight promising practices for building more robust engineering education research capabilities
3. Create future pathways to building engineering education research capabilities

Learning activities

1. Presentation of three previous practices (AREE, EER&I Networking, and REEP) for building engineering education research capabilities.
2. Small group reflection and dialogue on
    1. Three past practices for building research capabilities followed by brief report out. Below are some prompts to help guide this reflection:
        i. What aspects of the three previous practices resonated?
        ii. What do you think needs to be revived or refined?
        iii. How do you think these practices can help build engineering education research capabilities?
    2. Current practices and
    3. Identification of promising practices
3. Brief report out and whole group discussion of future pathways to building engineering education research capabilities.
4. Wrap-up of lessons learned and next steps

Special Session Part	Time	Notes
Welcome, introductions and overview	15 minutes	Introduction of panelists and participants. Overview of session
Presentation of Past Practices	30 minutes	Panelists will summarize, discuss lessons learned, implications and future prospects for AREE, EER&I and REEP
Small group discussion of past practices and current and potential future practices for building research capabilities.	30 minutes	Panelists will circulate to note recurring themes and insights

Whole group discussion and wrap up	15 minutes	Insights and lessons learned during the session and next steps

Why is a special session needed?

There is an urgent need to continue to improve engineering education and one key aspect is building engineering education research capabilities for research at the classroom, program, college, university, and industry levels. Research is essential to improving learning outcomes, recruitment and retention, broadening participation, and the health and wellbeing of our students, faculty, and graduates.

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