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Edited by Aditya Johri and Barbara M. Olds
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# Introduction

*Aditya Johri and Barbara M. Olds*

*The Cambridge Handbook of Engineering Education Research* (CHEER) is an important reference source for the growing field of engineering education research (EER). EER has become an increasingly important field internationally, as evidenced by the growing prestige and subscriber base of its key journal, the *Journal of Engineering Education (JEE)*, the founding of several Ph.D.-granting engineering education departments at prestigious institutions, and the growth of an international community of engineering education researchers who hold global meetings and have a variety of publication venues. Despite the growth of the field, there is currently no book that provides an overview of EER.[1] Thus we proposed CHEER with the belief that it will fill an important gap internationally in the EER field and will be used as a textbook for graduate courses, a reference book by engineering faculty in disciplinary engineering areas, and a resource by policymakers, K–12 engineering curriculum designers, informal science educators, and others.

Engineering education research draws on many social science disciplines in addition to disciplinary engineering knowledge and computing. Research in engineering education has traditionally focused on reporting of classroom interventions and generally lacked definition as a discipline until the late1990s and early 2000s. Since a landmark issue of *JEE* in 2005, which included papers by senior scholars in the field who argued for a stronger theoretical and empirically driven agenda for the field, engineering education has quickly emerged as a research driven field and subsequently has seen a substantial increase in both the quality and quantity of theoretical and empirical work. Research in engineering education is focused primarily on formal settings but work on informal learning in settings such as museums and after school programs is starting to appear. Chapters in this volume draw extensively on contemporary research in the learning sciences to include how technology affects learners and learning environments, and the role of social context in learning.

This volume contains thirty-five chapters organized into six sections authored by seventy-three scholars. We have selected these themes based on the research agenda developed for engineering education through a series of interdisciplinary colloquia funded by the U.S. National Science Foundation and published in the *Journal of Engineering Education* in October 2006.[2] We have modified the titles of the themes to make them fit better with a handbook but the intent remains the same. We have also added a theme to the five originally proposed. The first chapter, which is not part of any of the sections, provides a historical overview of engineering education research. The first section, "Engineering Thinking and Knowing," contains six chapters that focus on "research on what constitutes engineering thinking and knowledge within social contexts now and into the future." Part 2, "Engineering Learning Mechanisms and Approaches," contains six chapters and looks at "research on engineering learners' developing knowledge and competencies in context." Part 3, "Pathways into Diversity and Inclusiveness," explores "research on how diverse human talents contribute solutions to the social and global challenges and relevance of our profession" and consists of five chapters. In Part 4, "Engineering Education and Institutional Practices," five chapters highlight "research on the instructional culture, institutional infrastructure, and epistemology of engineering educators." Part 5, "Research Methods and Assessment," contains six chapters that focus on "research on, and the development of, assessment methods, instruments, and metrics to inform engineering education practice and learning." Finally, Part 6 "Cross-Cutting Issues and Perspectives," contains six chapters that address themes/topics that have emerged within engineering education research and have been pursued by a critical mass of scholars.

The authors of the handbook chapters represent the who's who of the engineering education research community and come from all corners of the world. Our goal in producing this handbook has been to publish an easily accessible volume that will be widely used by researchers in the field of engineering education but will also support the needs of students, engineering faculty, and policymakers.[3]

## Footnotes

1. The only current text that comprehensively addresses some issues relevant to EER is John Heywood's 2006 publication, *Engineering Education: Research and Development in Curriculum and Instruction*, which provides a synopsis of nearly 2,000 articles related to engineering education published since 1960. However, unlike this volume, Heywood's book provides only an overview to the field and its focus is not on recent theoretical and empirical developments in the social and learning sciences related to engineering education.
2. "The Research Agenda for the New Discipline of Engineering Education," *Journal of Engineering Education*, 94(4), pp. 259–261 (2006). DOI: 10.1002/j.2168-9830.2006.tb00900.x
3. Many authors refer to work that has appeared in the ASEE and FIE conferences and proceedings from those conference are available online at the following links:

   ASEE Conference Proceedings Search: http://www.asee.org/search/proceedings

   FIE IEEE Explore Digital Library: http://ieeexplore.ieee.org/xpl/conhome.jsp?punumber=1000297

CHAPTER 1

# Chronological and Ontological Development of Engineering Education as a Field of Scientific Inquiry

*Jeffrey E. Froyd and Jack R. Lohmann*

## Introduction

Engineering education as an area of interest for curriculum development and pedagogical innovation emerged in the United States in the period around 1890 to 1910 with the founding of the Society for the Promotion of Engineering Education (SPEE) in 1893 (American Society for Engineering Education, n.d.). Founding dates for a few other engineering education associations may provide some indication of when interest in engineering education emerged across the world: Internationale Gesellschaft für Ingenieurpadagogik (IGIP, 1972); Société Européenne pour la Formation des Ingénieurs (SEFI, 1973); and Australasian Association of Engineering Education (AAEE, 1989). Other associations interested in engineering education include Associação Brasileira de Educação em Engenharia (ABENGE), Asociación Nacional de Facultades y Escuelas de Ingenieria (ANFEI), International Association for Continuing Engineering Education (IACEE), Korean Society for Engineering Education (KSEE), Latin American and Caribbean Consortium of Engineering Institutions (LACCEI), and Mühendislik Dekanlari Konseyi (MDK). Given the date of the founding of the SPEE and historical data available on the society and its growth, in relation to similar information about other engineering education associations or societies, the authors have elected to use the chronology of events in the United States as the principal framework to describe the evolution of engineering education as a field of scientific inquiry with references to similar events internationally.

A transition, which is not nearly complete, to an interdisciplinary, more scholarly field of scientific inquiry into engineering education is occurring nearly 100 years later (Borrego & Bernhard, 2011; Continental, 2006; Haghighi, 2005; Jesiek, Newswander, & Borrego, 2009; Lohmann, 2005). Contextual factors, which are too numerous to describe exhaustively, have and will influence evolution of the field of engineering education research; however, the authors would like to draw attention to four important factors. First, although engineering is taught at K–12, undergraduate, and graduate levels, professional licensure currently requires a baccalaureate degree in engineering. Therefore, undergraduate education has been the primary avenue through which engineers enter the profession, and the literature in engineering education has focused predominantly on undergraduate education. As a result, research questions in undergraduate engineering education have tended to dominate attention of researchers; however, this is changing. Second, unlike mathematics and science education in K–12, K–12 engineering education has traditionally been lacking. As a result, research in K–12 engineering education has been minimal. However, the situation is changing. "Although K–12 engineering education has received little attention from most Americans, including educators and policy makers, it has slowly been making its way into U.S. K–12 classrooms. Today, several dozen different engineering programs and curricula are offered in school districts around the country, and thousands of teachers have attended professional development sessions to teach engineering-related coursework. In the past 15 years, several million K–12 students have experienced some formal engineering education" (Committee on K–12 Engineering Education; Linda Katehi, 2009, p. 1). As a result of increasing interest in engineering education in K–12, research questions associated with this focus are growing in importance. However, a large percentage of engineering faculty members, who traditionally have been viewed as primary stakeholders in findings from engineering education research, may not take much interest in findings from engineering education research in K–12. Third, research in education and the learning sciences can make significant contributions as researchers in any disciplinary-based educational field address their complex research questions (Froyd, Wankat, & Smith, 2012; Johri & Olds, 2011; also see Chapters 2 by Newstetter & Svinicki and 29 by Pellegrino, DiBello, & Brophy in this volume). However, much of the scholarly literature in education and the learning sciences has focused on precollege education, an area that traditionally has attracted less attention from most engineering faculty members (Johri & Olds, 2011), because of their focus on undergraduate education. It will take time and energy for familiarity and interest of engineering practitioners at the undergraduate level in research and learning sciences to reach a level that it begins to influence practice. Fourth, engineering educators, in general, receive little or no formal preparation for their instructional duties during their doctoral training or later as faculty. As a result, for most engineering faculty members, lack of familiarity with the education and learning sciences literature, reliance on familiar research methodologies that were often ill suited for educational studies, and complacency with accepting student satisfaction surveys as indicators of efficacy of course changes generated "a rich tradition of educational innovation, but until the 1980s assessment of innovation was typically of the 'We tried it and liked it and so did the students' variety" (Wankat, Felder, Smith, & Oreovicz, 2002, p. 217). Changing practice in engineering education so that faculty members apply findings in engineering education research, education research, and research in the learning sciences to their practice in engineering classrooms is a major challenge for engineering education practice and research (Jamieson & Lohmann, 2009, 2012).

Catalysts, including major National Science Foundation (NSF) funding for educational research and development beginning in the late 1980s and emergence of the outcomes-based ABET Engineering Criteria led to significant publications in engineering education research in the 1990s. In the last twenty years, engineering education research has begun to emerge as an interdisciplinary research field seeking its own theoretical foundations from a rich array of research traditions in the cognitive sciences; learning sciences; education; and educational research in physics, chemistry, and other scientific disciplines.

The remainder of the chapter is divided into two parts. First, we provide a brief chronology of the development of engineering education as a field of study. We then describe the ontological transformation of the field into engineering education research using criteria for defining the field of science education research (Fensham, 2004). A brief conclusion projects the near future of the field.

## The Chronological Evolution of U.S. Engineering Education as a Field of Scientific Inquiry

The first engineering program in the United States, civil engineering, was established at the United States Military Academy, which was founded in 1802 to reduce the nation's dependence on foreign engineers and artillerists in times of war (United States Military Academy, 2010). Other parts of the world also began engineering programs during the 1800s and especially the latter half of the century (Continental, 2006). Nonetheless, higher education was largely inaccessible to many Americans until the passage of the Morrill Act[1] in 1862 (Lightcap, 2010), which accelerated the nation's growth throughout the last half of the century fueled by such engineering efforts as the transcontinental railroad, electric power, the telegraph and telephone, and steam and internal combustion engines. Mechanical, electrical, and chemical engineering emerged as distinct disciplines toward the end of the nineteenth century and near the beginning of the twentieth century (Grayson, 1993). Other engineering disciplines, for example, industrial, biomedical, environmental, petroleum, mining, and nuclear, emerged during the twentieth century.

For the first half of the twentieth century, U.S. engineering and engineering education was characterized by its practical arts (Seely, 1999; also see Chapter 7 by Stevens, Johri, & O'Connor in this volume). This focus changed abruptly when the world observed the power of science and its applications during World War II (Seely, 1999). When coupled with creation of NSF in 1950 (National Science Foundation [NSF], 2010), and several other programs within existing federal agencies, federal funding largely transformed the American higher education system into research-based institutions of higher learning, especially in science and engineering. Engineering education shifted from hands-on, practicum-oriented curricula to ones that emphasized mathematical and scientific foundations (Grayson, 1993; Seely, 1999). The shift was codified when ASEE issued its landmark study commonly called the Grinter Report in 1955 (American Society for Engineering Education, 1994). It outlined more research-oriented and science-based curricula, from which initial transitions to more design-oriented curricula are recent occurrences (Froyd et al., 2012).

The first engineering society, the American Society of Civil Engineers, was established in 1852 (American Society of Civil Engineers, 2010) and the first engineering education society, the Society for the Promotion of Engineering Education (SPEE), was founded in 1893 (Reynolds & Seely, 1993) and is now known as the American Society for Engineering Education (ASEE). As mentioned in the introduction, the growth of similar engineering education societies appears to have occurred mostly after the Second World War (*Journal of Engineering Education*, 2010). SPEE established the first periodical "devoted to technical education" in 1910, called the *Bulletin* (American Society for Engineering Education, 1910), which nearly a century later evolved into the discipline-based (engineering) education research journal *Journal of Engineering Education* (*Journal of Engineering Education*, 2010; Lohmann, 2003).

In 1986, the National Science Board issued an overdue wake-up call about the state of U.S. engineering, mathematics, and science education (National Science Board, 1986). Its report provided a number of recommendations and made clear that one among them played a critical role: "The recommendations of this report make renewed demands on the academic community – especially that its best *scholarship* be applied to the manifold activities needed to strengthen undergraduate science, engineering, and mathematics education in the United States" (National Science Board, 1986, p. 1, emphasis added). It was instrumental in reviving the NSF's role to "initiate and support science and engineering education programs at all levels and in all the various fields of science and engineering" (NSF, 2006, p. 5). The report was also among those that sparked a vigorous national dialogue on the role of scholarship in improving the quality of U.S. higher education. For example, the highly influential 1990 report, "Scholarship Reconsidered: Priorities of the Professoriate," by Ernest Boyer of the Carnegie Foundation, offered a new taxonomy and terminology to describe academia's multifaceted forms of scholarship (Boyer, 1990). In engineering, introduction of EC2000 by ABET in the 1990s was a major driver to improve the quality of engineering education (ABET, 1995; Prados, 2005). Its outcomes-focused, evidence-based cycle of observation, evaluation, and improvement characterized many aspects of a scholarly approach to educational innovation.

Dialogue and decisions made in the 1990s paved the way for engineering education to become a field of scientific inquiry as it became increasingly clear that the intuition-based approaches of the past were not producing the quantity and quality of engineering talent needed to address society's challenges (Continental, 2006; National Academy of Engineering [NAE], 2004; National Research Council [NRC], 2005; NSF, 1992). More scholarly and systematic approaches based on the learning sciences were needed (Gabriele, 2005; Haghighi, 2005; NRC, 2000, 2002); concurrently, research on engineering science should contribute to the development of the learning sciences (Johri, 2010; Shulman, 2005), especially in areas closely linked to engineering, such as design. Consequently, embryonic and globally diverse communities began to emerge and collaborate such that by the mid-2000s engineering education as a scientific field of inquiry (research) had passed the "tipping point" both within the United States and elsewhere (Borrego & Bernhard, 2011; Jesiek, Borrego, & Beddoes, 2010). Integrating and expanding these communities was a major point of discussion in a recent NSF-funded ASEE study, Creating a Culture for Scholarly and Systematic Innovation in Engineering Education (Jamieson & Lohmann, 2009, 2012).

For a more detailed chronological description of the development of engineering education and engineering education, the authors (together with the support of others in the engineering education research community [please see Acknowledgments]) have compiled a timeline in Appendix 1.1. In the next section, we describe the current state of engineering education research, much of it having been created within the last decade or so. Figure 1.1 presents a picture of the largest authorship network within engineering education research and shows a core group that is linked to several other groups and nodes on peripheries.

## An Ontological Description of the State of Engineering Education Research

A chronological description of a field of research uses time and temporal ordering as its organizational framework. An alternative organizational framework describes entities and relationships among the entities, that is, a conceptualization (Genesereth & Nilsson, 1987). To describe a conceptualization of the state of engineering education research requires an ontology, that is, a specification for a conceptualization (Gruber, 1993). An ontology for evaluating maturation of fields of disciplinary-based education research has been formulated with three categories of criteria: structural, research, and outcome, as summarized in Table 1.1 (Fensham, 2004). We believe this framework is appropriate for organizing and critiquing the evolution and maturity of engineering education research.

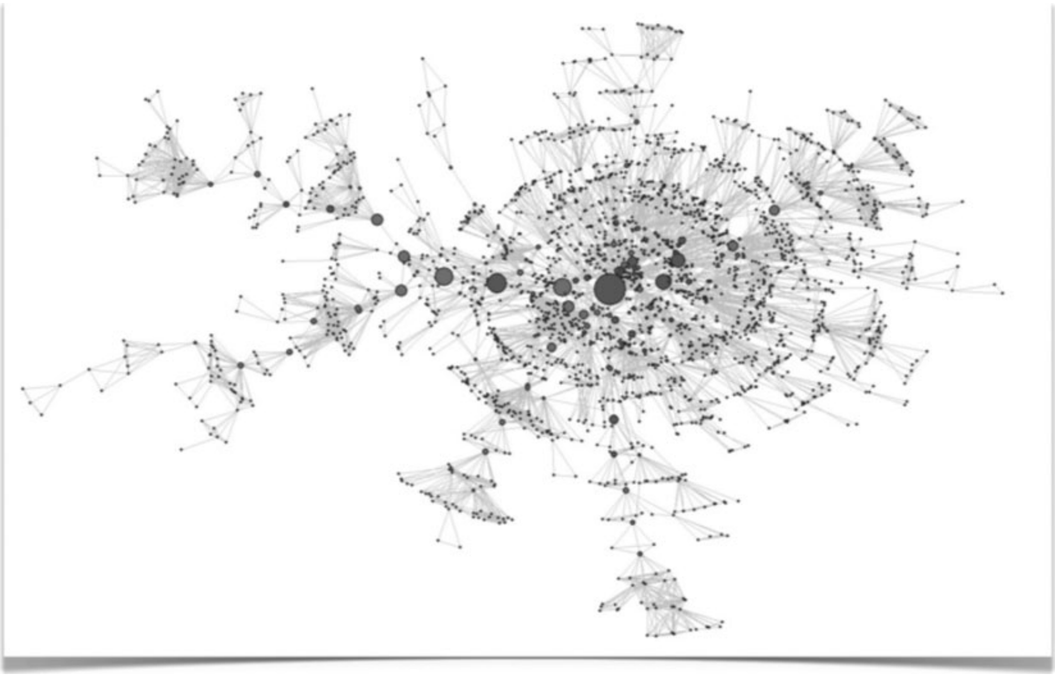

**Figure 1.1.** The largest co-author network in EER. (From Madhavan et al., 2011. Reprinted with permission.)

**Table 1.1.** Fensham's (2004) Criteria for Defining the Field of Science Education Research

| *Category* | *Criteria* | *Exemplars of Criteria* |
|---|---|---|
| Structural | Academic Recognition | Full faculty appointments in the area of research |
| | Research Journals | Successful journals for reporting quality research |
| | Professional Associations | Healthy national and international professional associations |
| | Research Conferences | Regular conferences for the direct exchange of research that enable researchers to meet in person |
| Research | Scientific Knowledge | Knowledge of science content required to conduct the research |
| | Asking Questions | Asking distinctive research questions not addressed by other fields |
| | Conceptual and Theoretical Development | Theoretical models with predictive or explanatory power |
| | Research Methodologies | Invention, development, or at least adaptation of methodologies, techniques, or instruments |
| | Progression | Researchers are informed by previous studies and build on or deepen understanding |
| | Model Publications | Publications that other researchers hold up as models of conduct and presentation of research studies in the field |
| | Seminal Publications | Publications recognized as important or definitive because they marked new directions or provided new insights |
| Outcome | Implications for Practice | Outcomes from research that are applications to the practice of science education |

***Structural Criteria***

1. *Academic Recognition:* Academic recognition examines extent to which scholars in the field are recognized by their institutions. One metric for recognition is establishment of organizational units for scholarship in the discipline, that is, centers for engineering education research. In Europe, a "specific goal of the Bologna declaration is to promote mobility amongst engineering students in Europe. As a consequence, universities will have to engage in an international competition to attract students. This results in a growing interest for improvement and innovation in engineering education. All over Europe "Centres of Expertise on Learning and Teaching" are being established or, in case of older existing institutes are re-installed. The position of a centre of this kind within the university organisation varies as well as tasks and responsibilities. Some establishments are divided into a research group and a teacher-training and consultant division" (Hawwash, 2007, p. 30). In the United States, there are about twenty centers involved in engineering education research of which most were established in the last decade (Center for the Advancement of Scholarship in Engineering Education, 2010). Departments of Engineering Education were established at Purdue and Virginia Tech, and were the first to provide tenured positions in engineering education. Later, Utah State University established a Department of Engineering Education and Clemson University established a Department of Engineering and Science Education.
2. *Research Journals:* The field has one journal focused exclusively on research, the *Journal of Engineering Education* (JEE), and five whose missions encompass research: *Engineering Studies*, *European Journal of Engineering Education* (EJEE), *International Journal of Engineering Education* (IJEE), *Engineering Education*, and *Chemical Engineering Education* (Borrego & Bernhard, 2011).[2] Two are listed on Thomson-Reuters citation indices (IJEE and JEE) and three are ranked by the Australian Research Council (EJEE, IJEE, and JEE).
3. *Professional Associations and Research Conferences:* There are many international engineering education societies including a federation of such societies (International Federation of Engineering Education Societies, 2010). The dominant ones are ASEE, the Australasian Association for Engineering Education (AAEE), and the Société Européenne pour la Formation des Ingénieurs (SEFI). Annual conferences focus on curriculum development; however, increasingly some host engineering education research tracks and some have groups whose focus is engineering education research, notably AAEE, ASEE, and SEFI. An independent research symposium Research on Engineering Education Symposium (REES) was established in 2007 to facilitate a periodic global gathering of researchers in the field (Research in Engineering Education Network, 2010).
4. *Funding and Honors:* The authors believe there are two additional structural criteria of importance to engineering. Peer-reviewed extramural support has been a critical to U.S. engineering research since World War II. Educational initiatives, however, have been supported mostly within university budgets. In the late 1980s, the NSF established programs for curriculum development and pedagogical innovation whose support mirrored their technical research counterparts, and a number of programs are now available for discipline-based education research. Awards and honors for teaching are ubiquitous but recognitions for engineering education research are nearly nonexistent. Two publication awards include ASEE's Wickenden Award for the best paper published annually in JEE and the Outstanding Research Publication Award by Division I (Education in the Professions) of the American Educational Research Association.

***Research Criteria***

1. *Scientific Knowledge and Asking Questions:* The NSF-funded Engineering Education Research Colloquies held in 2004–2005 were among the more notable efforts to begin to frame a scientific basis for thinking about the research challenges in the field of engineering education (The Steering Committee of the National Engineering Education Research Colloquies, 2006a, 2006b). They produced a taxonomy organized around "five priority research areas (Engineering Epistemologies, Engineering Learning Mechanisms, Engineering Learning Systems, Engineering Diversity and Inclusiveness, and Engineering Assessment)" that merge disciplinary engineering and learning sciences knowledge. Other efforts have recently emerged in the European community (Borrego & Bernhard, 2011; European and Global Engineering Education Network, 2010). Although the global community has not reached consensus on a taxonomy, it clearly feels a pressing need for such and is working to develop it (Borrego & Bernhard, 2011).
2. *Conceptual and Theoretical Development and Research Methodologies:* These two areas form the intellectual core of any disciplinary-based educational research field. Currently, conceptual and theoretical frameworks and research methodologies in engineering education research show considerable similarity to those of educational research in general, a condition that reveals its lack of maturity. Like other educational research fields, one foundation is research in the learning sciences, with its vast literature base and different theoretical frameworks (Greeno, Collins, & Resnick, 1996). At present, theoretical frameworks for research in engineering education do not distinguish themselves itself from frameworks for educational research in general, which tend to emphasize individual learning. Research in the cognitive sciences, for example, brain physiology, might contribute to a theoretical framework; however, constructing bridges from functions of individual or small groups of neurons to complex engineering concepts and processes would be a formidable task (Johri & Olds, 2011). Also, because engineering faculty members teach as collections or organizations of individuals, a potential contributor to future theoretical frameworks may be organizational change (Weick & Quinn, 1999).

Similar statements can also be made about applicable research methodologies, that is, engineering education research does not have a distinctive set of research methodologies. Engineering faculty members who apply engineering education research have backgrounds that condition them to understand quantitative research methodologies more easily than qualitative or mixed methodologies. As a result, efforts have been made to educate a large segment of the audience for engineering education research about the nature and value of the latter two sets of methodologies (Borrego, Douglas, & Amelink, 2009), but further progress is required.

3. *Progression, Models, and Seminal Publications:* Strobel, Evangelou, Streveler, and Smith (2008) think the first doctoral thesis on engineering education was published in 1929, and additional theses appeared occasionally up to about 1980. However, for the years between 1980 and 1989, they found five to eleven theses published every year; thereafter, thesis production increased markedly, and several widely cited articles on research in engineering education were published (Atman, Chimka, Bursic, & Nachtmann, 1999; Besterfield-Sacre, Atman, & Shuman, 1997; Felder, Felder, & Dietz, 1998) in the 1990s. These papers laid foundations for (i) further understanding of how students learn the engineering design process and how verbal protocol analysis methodologies can support the research (Atman & Bursic, 1998; Atman et al., 1999); (ii) rigorous assessment and adoption of cooperative learning (and later, other innovations) in engineering (Felder

et al., 1998; Haller, Gallagher, Weldon, & Felder, 2000); and (iii) the importance of and instruments for understanding engineering student attitudes and the roles they play in retention and learning (Besterfield-Sacre et al., 1997). In the first decade of the new millennium, significant publications in engineering education research have become too numerous to mention in this short review.

### *Outcome Criteria (Implications for Practice)*

One key set of criteria in evaluating maturity of any research field are its influences on practice. Examining one metric related to the criteria was a survey of engineering department chairs about the extent to which seven innovations in engineering education had been adopted in engineering departments (Borrego, Froyd, & Hall, 2010). Each of the innovations was well supported by research demonstrating its efficacy. Survey results showed that engineering department chairs were aware of the innovations, but adoption of the innovations lagged well behind awareness. These findings in engineering echo similar findings in physics education (Dancy & Henderson, 2012).

Anticipating these findings, in 2006, ASEE launched a major initiative in engineering education community to persuade members of the synergistic and complementary roles played by innovation and research, beginning with the ASEE Year of Dialogue. Culmination of this initiative was publication of two ASEE reports: *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education* (Jamieson & Lohmann, 2009) and *Innovation with Impact* (Jamieson & Lohmann, 2012). However, the fact that such an initiative was required is indicative of a culture in which most engineering education practitioners are content to continue to focus on innovations and less concerned about theoretical foundations that might catalyze innovations or methodologies with which the efficacy of the innovations might be evaluated.

Other factors besides a focus on innovations contribute to the lack of influence of engineering education research on practice in engineering classrooms. Research in physics education suggests that researchers expect that their curricular innovations will be adopted by faculty members "with minimal changes, while faculty expect researchers to work with them to incorporate research-based knowledge and materials into their *unique* instructional situations" (Henderson & Dancy, 2008, p. 79, emphasis added). For example, a study of adoption of research-based instructional strategies by chemical engineering faculty members showed that the primary faculty concern was classroom time that might be required to implement the instructional strategy (Prince, Borrego, Cutler, Henderson, & Froyd, 2013), but efficacy with respect to student learning is often a primary focus when evaluating an instructional strategy. Other factors that influence adoption lie outside of the control of an individual faculty member. These include student attitudes toward school (Henderson & Dancy, 2007); expectations of content coverage (J. L. Cooper, MacGregor, Smith, & Robinson, 2000; M. M. Cooper, 1995; Henderson & Dancy, 2007), which may be linked to classroom time; time required to prepare a lecture period (Henderson & Dancy, 2007; Prince et al., 2013); departmental norms (Henderson & Dancy, 2007); student resistance (J. L. Cooper et al., 2000; Henderson & Dancy, 2007); class size and room layout (M. M. Cooper, 1995; Henderson & Dancy, 2007); and constraints imposed by how class periods are scheduled (Henderson & Dancy, 2007).

In addition to the aforementioned factors, numerous articles have suggested that adoption of innovations from disciplinary-based educational research, educational research, and research in the learning sciences is hindered by institutional reward systems that value research far more than they value teaching (Cuban, 1999; Diamond, 1993; Handelsman et al., 2004). An often-repeated rationale for emphasis on research is that quality in research and teaching are