Fundamentals of Engineering Education Research
Rigorous Research in Engineering Education Initiative
(NSF DUE 0817461)
CLEERhub.org

Overview
What are we going to do?

• Welcome and introductions
• Topics of the workshop
  – Background and context
  – Features of engineering education research
  – Research questions and methodologies
  – Print and online resources
  – Global communities and their networks
• Format of the workshop
  – Interactive and team-based work
When and how did you become interested in engineering education research and/or innovation?

Was there a critical incident or memorable event associated with your initial interest?

Workshop frame of reference

- Workshop is about
  - Identifying faculty interested in engineering education research
  - Deepening understanding of engineering education research
  - Building engineering education research capabilities
- Workshop is NOT about
  - Pedagogical practice, i.e., “how to teach”
  - Convincing you that good teaching is important
  - Writing engineering education research grant proposals or papers
  - Advocating all faculty be engineering education researchers
Levels of inquiry in engineering education

• **Level 0** Teacher
  – Teach as taught

• **Level 1** Effective Teacher
  – Teach using accepted teaching theories and practices

• **Level 2** Scholarly Teacher
  – Assesses performance and makes improvements

• **Level 3** Scholar of Teaching and Learning
  – Engages in educational experimentation, shares results

  • **Level 4** Engineering Education Researcher
  – Conducts educational research, publishes archival papers

**Source:** Streveler, R., Borrego, M. and Smith, K.A. 2007. Moving from the “Scholarship of Teaching and Learning” to “Educational Research:” An Example from Engineering. *Improve the Academy,* Vol. 25, 139-149.

Workshop Intentions / Participant Learning Outcomes

1. Describe key features of engineering education research
2. Explain emergence of engineering education research as a discipline
3. Describe recent reports and their relevance for and relationship with engineering education research
4. Summarize growth of engineering education research
5. Speculate on the future of engineering education research
Some history about this workshop

• **Rigorous Research in Engineering Education (RREE1)**
  - One-week summer workshop, year-long research project
  - Funded by National Science Foundation (NSF), 2004-2006
  - About 150 engineering faculty participated

• **Goals**
  - Identify engineering faculty interested in conducting engineering education research
  - Develop faculty knowledge and skills for conducting engineering education research (especially in theory and research methodology)
  - Cultivate the development of a Community of Practice of faculty conducting engineering education research

---

RREE Approach

![Diagram of RREE Approach]

**Theory**
(study grounded in theory/conceptual framework)

Research that makes a difference . . . in theory and practice

**Research**
(appropriate design and methodology)

**Practice**
(implications for teaching)

http://inside.mines.edu/research/cee/ND.htm
Research can be inspired by ...

<table>
<thead>
<tr>
<th>Understanding (Basic)</th>
<th>Use (Applied)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Pure basic research (Bohr)</td>
</tr>
<tr>
<td>No</td>
<td>Pure applied research (Edison)</td>
</tr>
</tbody>
</table>


RREE2

Follow-up proposal (RREE2)

- Includes a series of 5 short courses*
  - Fundamentals of Engineering Education Research
  - Selecting Conceptual Frameworks
  - Understanding Qualitative Research
  - Designing Your Research Study
  - Collaborating with Learning and Social Scientists

*Recorded and posted on CLEERhub.org
## Today’s objectives

- Identify principal features of engineering education research
- Frame and situate research questions and methodologies
- Gain familiarity with several print and online resources
- Become aware of global communities and their networks

## What does high-quality research in your discipline look like?

- What are the **qualities, characteristics, or standards** for **high-quality** research in your discipline?
- Think of it this way: “**Research in my field is high-quality when...**”

☞ Individually, list the qualities, characteristics or standards in your discipline

☞ Compare your lists, and as a group, develop a list of high-quality research qualities, characteristics or standards
What does high-quality research in your discipline look like?

• (Workshop list)

What are the qualities, characteristics, or standards for high-quality education research in your discipline?

Individually, list:

1) Which qualities, characteristics, or standards identified in the previous list DO NOT apply?

2) What qualities, characteristics, or standards can you envision that are DIFFERENT for education research?

As a group, combine your lists.

---

What does education research in your discipline look like?

• What are the qualities, characteristics, or standards for high-quality education research in your discipline?

Individually, list:

1) Which qualities, characteristics, or standards identified in the previous list DO NOT apply?

2) What qualities, characteristics, or standards can you envision that are DIFFERENT for education research?

As a group, combine your lists.
Guiding principles for scientific research in education

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

- How do our lists compare with the NRC six?
- Is a global list possible? Do cultural contexts matter?

Source: Scientific Research in Education, National Research Council, 2002

The research process and reasoning

Practical Problem

Research Question

Research Answer

Research Problem

Research Process

Claim → Reason → Evidence

Warrant

Acknowledgment and Response

Research Reasoning
Most common frameworks in educational research

• Theories of learning
• Theories of motivation
• Theories of development
• Theories of contextual effects


Multiple theoretical frameworks

Which comes first: framework or observation?
Can go in either direction
Multiple theoretical frameworks

Going from framework to research question to research study

Framework
Self-determination framework says - students’ motivation for a task is affected by the degree of control they have over it.

Therefore
If we manipulate the degree of student control, we should see variations in motivation levels.

Design
Different groups are given different degrees of control over the topic and process of their project and their motivation for the project is measured at various times throughout the semester.

Going from observation to framework to research question to research study and back to observation

Observation
Some students in a class participate more than others.

Possible Frameworks
• Learning theory: Prior knowledge differences
• Motivation theory: Goal orientations, task value, self-efficacy
• Contextual variables: Course contingencies; classroom climate

Design possibilities
• Measure and regress level of participation on potential variables.
• Manipulate course contingencies or course practices.
Books, journals, online resources

- The Craft of Research
- Scientific Research in Education
- Journal of Engineering Education (JEE)
- Thomson ISI Citation Index
- Some other journals

What is your experience?

- Silently reflect on your experience with engineering education research
- Jot down
  - What has been the most exciting opportunity for you in this area?
  - What has been the most difficult challenge you have faced?
- Share with the person next to you
Becoming an Engineering Education Researcher—Adams, Fleming & Smith

1. Find and follow your dream.
2. Find and build community.
3. Do your homework. Become familiar with engineering education research.
4. Remember what it is like to be a student—be open to learning and the associated rewards and challenges.
5. Find balance. You will feel like you have multiple identities.
6. Be an architect of your own career.
7. Wear your researcher “lenses” at all times.
8. Use research as an opportunity for reflective practice.

Groups, centers, departments...

Engineering education societies...


Conferences with engineering education research presentations:

- **ASEE** — Annual Conference, American Society for Engineering Education, see www.asee.org
- **FIE** — Frontiers in Education, sponsored by ERM/ASEE, IEEE Education Society and Computer Society, fie-conference.org/erm
- **AAEE** — Annual Conference, Australasian Association for Engineering Education, see www.aaee.com.au
- **GCEE** — Global Colloquium on Engineering Education, sponsored by ASEE and local partners where the meeting is held, see www.asee.org
- **SEFI** — Annual Conference, Société Européenne pour la Formation des Ingénieurs, see www.sefi.be
- **REES** — Research on Engineering Education Symposium, rees2009.pbwiki.com/
- **SASEE** — South African Society for Engineering Education,
Expanding and sustaining research capacity in engineering and technology education: Building on successful programs for faculty and graduate students

Collaborative partners: Purdue (lead), Alverno College, Colorado School of Mines, Howard University, Madison Area Technical College, National Academy of Engineering

CLEERhub.org
**Discipline-Based Education Research (DBER)**

- Discipline-based education research (DBER) is a **small but growing field of inquiry**.
- Conducting DBER and using DBER findings are **distinct but interdependent** pursuits.
- DBER is inherently **interdisciplinary**.
- Individual fields of DBER have made **notable inroads** in terms of establishing their fields but still face challenges in doing so.
- **Blending** a scientific/engineering discipline with education research poses **unique professional challenges for DBER scholars**.
- There are **many pathways to becoming a discipline-based education researcher**.

**Discipline-Based Education Research Timeline**

- Engr. Sci. Reform
- Curricula Reform
- EC2000
- EER
- Geoscience
- Biology ER
- Curricula Reform
- Chemistry ER
- Curricula Reform
- Physics ER
- Medical ER

*DBER is located in the relevant disciplinary school, e.g. medicine, physics.*
Discipline-Based Education Research (DBER)
Understanding and Improving Learning in Undergraduate Science and Engineering

http://www.nap.edu/catalog.php?record_id=13362

Undergraduate Science and Engineering Education: Goals

• Provide all students with foundational knowledge and skills
• Motivate some students to complete degrees in science or engineering
• Support students who wish to pursue careers in science or engineering
Undergraduate Science and Engineering Education: Challenges and Opportunities

- Retaining students in courses and majors
- Increasing diversity
- Improving the quality of instruction

What is Discipline-Based Education Research?

- Emerging from various parent disciplines
- Investigates teaching and learning in a given discipline
- Informed by and complementary to general research on human learning and cognition
Study Charge

• Synthesize empirical research on undergraduate teaching and learning in physics, chemistry, engineering, biology, the geosciences, and astronomy.

• Examine the extent to which this research currently influences undergraduate science instruction.

• Describe the intellectual and material resources that are required to further develop DBER.

Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research

• SUSAN SINGER (Chair), Carleton College
• ROBERT BEICHNER, North Carolina State University
• STACEY LOWERY BRETZ, Miami University
• MELANIE COOPER, Clemson University
• SEAN DE C ATUR, Oberlin College
• JAMES FAIRWEATHER, Michigan State University
• KENNETH HELLER, University of Minnesota
• KIM KASTENS, Columbia University
• MICHAEL MARTINEZ, University of California, Irvine
• DAVID MOBK, Montana State University
• LAURA R. NOVICK, Vanderbilt University
• MARCY OSGOOD, University of New Mexico
• TIMOTHY F. SLATER, University of Wyoming
• KARL A. SMITH, University of Minnesota and Purdue University
• WILLIAM B. WOOD, University of Colorado
Structure of the Report

• Section I. Status of Discipline-Based Education Research
• Section II. Contributions of Discipline-Based Education Research
• Section III. Future Directions for Discipline-Based Education Research

Section I. Status of Discipline-Based Education Research
Status of DBER: Goals

• Understand how people learn the concepts, practices, and ways of thinking of science and engineering.
• Understand the nature and development of expertise in a discipline.
• Help to identify and measure appropriate learning objectives and instructional approaches that advance students toward those objectives.
• Contribute to the knowledge base in a way that can guide the translation of DBER findings to classroom practice.
• Identify approaches to make science and engineering education broad and inclusive.

Status of DBER: Types of Knowledge Required To Conduct DBER

• Deep disciplinary knowledge
• The nature of human thinking and learning as they relate to a discipline
• Students’ motivation to understand and apply findings of a discipline
• Research methods for investigating human thinking, motivation, and learning
Status of DBER: Conclusions

• DBER is a collection of related research fields rather than a single, unified field. (Conclusion 1)

• High-quality DBER combines expert knowledge of:
  – a science or engineering discipline,
  – learning and teaching in that discipline, and
  – the science of learning and teaching more generally.
  (Conclusion 4)

Section II. Contributions of Discipline-Based Education Research
Contributions of DBER: Conceptual Understanding and Conceptual Change

• In all disciplines, undergraduate students have incorrect ideas and beliefs about fundamental concepts. (Conclusion 6)

• Students have particular difficulties with concepts that involve very large or very small temporal or spatial scales. (Conclusion 6)

• Several types of instructional strategies have been shown to promote conceptual change.

Contributions of DBER: Problem Solving and the Use of Representations

• As novices in a domain, students are challenged by important aspects of the domain that can seem easy or obvious to experts. (Conclusion 7)

• Students can be taught more expert-like problem-solving skills and strategies to improve their understanding of representations.
Contributions of DBER: Research on Effective Instruction

- Effective instruction includes a range of well-implemented, research-based approaches. (Conclusion 8)

- Involving students actively in the learning process can enhance learning more effectively than lecturing.

Section III. Future Directions for Discipline-Based Education Research
Future Directions for DBER: Translating DBER into Practice

- Available evidence suggests that DBER and related research have not yet prompted widespread changes in teaching practice among science and engineering faculty. (Conclusion 12)

- Efforts to translate DBER and related research into practice are more likely to succeed if they:
  - are consistent with research on motivating adult learners,
  - include a deliberate focus on changing faculty conceptions about teaching and learning,
  - recognize the cultural and organizational norms of the department and institution, and
  - work to address those norms that pose barriers to change in teaching practice. (Conclusion 13)

Future Directions for DBER: Recommendations for Translating DBER Into Practice

- **RECOMMENDATION:** With support from institutions, disciplinary departments, and professional societies, faculty should adopt evidence-based teaching practices.

- **RECOMMENDATION:** Institutions, disciplinary departments, and professional societies should work together to prepare current and future faculty to apply the findings of DBER and related research, and then include teaching effectiveness in evaluation processes and reward systems throughout faculty members’ careers. (Paraphrased)
Future Directions for DBER: Advancing DBER through Collaborations

- Collaborations among the fields of DBER, and among DBER scholars and scholars from related disciplines, although relatively limited, have enhanced the quality of DBER. (Conclusion 15)

Future Directions for DBER: Research Infrastructure

- Advancing DBER requires a robust infrastructure for research. (Conclusion 16)

- **RECOMMENDATION**: Science and engineering departments, professional societies, journal editors, funding agencies, and institutional leaders should:
  - clarify expectations for DBER faculty positions,
  - emphasize high-quality DBER work,
  - provide mentoring for new DBER scholars, and
  - support venues for DBER scholars to share their research findings
Future Directions for DBER: Some Key Elements of a Research Agenda

• Studies of similarities and differences among different groups of students
• Longitudinal studies
• Additional basic research in DBER
• Interdisciplinary studies of cross-cutting concepts and cognitive processes
• Additional research on the translational role of DBER

Acknowledgements

• National Science Foundation, Division of Undergraduate Education (Grant No. 0934453)
• Various volunteers:
  – Committee
  – Fifteen reviewers
  – Report Review Monitor (Susan Hanson, Clark University) and Coordinator (Adam Gamoran, University of Wisconsin-Madison)
• Commissioned paper authors
• NRC staff (Natalie Nielsen, Heidi Schweingruber, Margaret Hilton)
Seven Recommendations for Innovation with Impact

Who
2. Expand collaborations.

What
3. Expand efforts to make engineering more engaging, relevant, and welcoming.

How
4. Increase, leverage, and diversify resources for engineering teaching, learning, and innovation.
5. Raise awareness of proven practices and of scholarship in engineering education.

Creating a Better Culture

To measure progress in implementing policies, practices, and infrastructure in support of scholarly and systematic innovation in engineering education:

6. Conduct periodic self-assessments in our individual institutions.

1. a shift from hands-on and practical emphasis to engineering science and analytical emphasis;
2. a shift to outcomes-based education and accreditation;
3. a shift to emphasizing engineering design;
4. a shift to applying education, learning, and socialbehavioral sciences research;
5. a shift to integrating information, computational, and communications technology in education.

What Are Your Plans?

- Silently reflect on your interests and plans for applying and/or supporting engineering education research, or becoming an engineering education researcher.
- Jot down
  - What do you plan to do next?
  - What are your longer range plans?
- Share with the person next to you
Thank you!

An e-copy of this presentation will be posted to:
http://CLEERhub.org
http://www.ce.umn.edu/~smith/links.html