Fundamentals of Engineering Education Research
Rigorous Research in Engineering Education Initiative (NSF DUE 0817461)
https://stemehub.org/groups/cleerhub

Texas State University – San Marcos – October 6, 2017

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A Workshop on Building Capability and Communities in Engineering Education Research sponsored by the National Science Council National Ping Tung University of Science and Technology Meiho Institute of Technology in partnership with Annals of Research in Engineering Education Journal of Engineering Education Rigorous Research in Engineering Education Initiative

Kaohsiung—Taipei, Taiwan • 2-5 February 2009

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Georgia Institute of Technology

Karl A. Smith
Purdue University and University of Minnesota
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

Who’s here?

• Your workshop leaders
  👉• Introduce yourself to those near you
Engineering Education Research and/or Innovation STORY

• 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

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

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)

Research can be inspired by ...

Use (Applied)

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure basic research (Bohr)</td>
<td>Use-inspired basic research (Pasteur)</td>
<td></td>
</tr>
<tr>
<td>Pure applied research (Edison)</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Understanding (Basic)

Yes

No

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*
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 https://stemedhub.org/groups/cleerhub

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
Objective 1

Identify principal features of engineering education research

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?

- \( (\text{Workshop list}) \)
- \( (\text{Workshop list}) \)

What does education research in your discipline look like?

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

左手 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?

左手 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?


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1. **Significant questions** that can be investigated **empirically**

- **Who would care about your results?**
- **What data will you need to gather to answer your question?**
2. Link research to relevant theory

- Learning theories
  - Cognition
  - Novice – expert differences
  - Instructional psychology
  - Psychometrics
- Motivational theories
- Moral and ethical development
- Social context of education

3. Methods for direct investigation (examples)

**Quantitative methods**
- Tests
- Surveys & questionnaires (defined response)
- Faculty or peer ratings

**Qualitative methods**
- Focus groups
- Interviews
- Observations
4. Reasoning

What makes a convincing argument

• Builds on what others have done before (literature)
• Theoretical foundation – make sense of results within existing frameworks of learning and teaching
• Methodology is explicit and appropriate
  • Instruments are reliable and valid
• Strength of observed relationships
• Elimination of alternative explanations
  • Study design
  • Confounding variables

5. Replicate and generalize – use the results

Setting the results in a larger context

• MUST know the literature
• Strict replication is rare in educational research
  • Transferable with extension - to new topic, setting, learners, etc.
6. Disclose

- Scholarly journals
- Conference presentations

- Peer-review is the core issue
  - One of the few quality controls we have
Objective 2

Frame and situate research questions and methodologies

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.
Multiple theoretical frameworks

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.

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
Objective 3  
Gain familiarity with several print and online resources

Books, journals, online resources

<table>
<thead>
<tr>
<th>Books, journals, online resources</th>
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<tbody>
<tr>
<td>- The Craft of Research</td>
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<tr>
<td>- Scientific Research in Education</td>
</tr>
<tr>
<td>- Journal of Engineering Education (JEE)</td>
</tr>
<tr>
<td>- Science Citation Index</td>
</tr>
<tr>
<td>- Some other journals</td>
</tr>
</tbody>
</table>
## Engineering Education Departments and Programs (Graduate)

Global Calls for Reform

### Engineering/STEM Education Graduate Programs

<table>
<thead>
<tr>
<th>Institution</th>
<th>Program</th>
<th>Degree/Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona State University</td>
<td>Dept. of Education Technology</td>
<td>M.Ed., Ph.D., Ed.D. in Education Technology</td>
</tr>
<tr>
<td>University of California, Berkeley</td>
<td>School of Engineering, Science and Mathematics (U.S. &amp; International)</td>
<td>M.S., Ph.D. in Engineering Education, Ph.D. in Engineering and Public Policy</td>
</tr>
<tr>
<td>University of California, Irvine</td>
<td>Department of Civil &amp; Environmental Engineering</td>
<td>M.S. in Civil Engineering, Ph.D. in Civil Engineering</td>
</tr>
<tr>
<td>University of Michigan, Dearborn</td>
<td>College of Engineering</td>
<td>M.S., Ph.D. in Engineering Education</td>
</tr>
<tr>
<td>University of Pittsburgh</td>
<td>School of Engineering, Science and Technology</td>
<td>M.Ed., Ph.D. in Engineering Education</td>
</tr>
<tr>
<td>University of California, Los Angeles</td>
<td>Institute of Engineering Education, University of California, Los Angeles</td>
<td>Ph.D. in Engineering Education</td>
</tr>
<tr>
<td>Texas A&amp;M University</td>
<td>College of Engineering</td>
<td>M.S., Ph.D. in Engineering Education</td>
</tr>
<tr>
<td>Boise State University</td>
<td>College of Education</td>
<td>M.S., Ph.D. in Education</td>
</tr>
<tr>
<td>North Carolina State University</td>
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</tbody>
</table>

**Research-based Transformation**

**K-12 Engineering**

Global Calls for Reform

http://tinyurl.com/engredu
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

DBER Departments and Graduate Programs

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

ASEE Reports - A Path Forward
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.

https://www.asee.org/member-resources/reports/Innovation-with-Impact

Seven Recommendations for Innovation with Impact (continued)
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.

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&tp=&amnumber=6185632

Objective 4

Become aware of global communities and their networks
An emerging global community

- Groups, centers, departments
- Engineering education societies
- Forums for dissemination

What follows is a sample — it is NOT an exhaustive list!

Groups, centers, departments...

- **Engineering Education Centers** — Australia: UICEE, UNESCO International Centre for Engineering Education; Denmark: UCPBLEE, UNESCO Chair in Problem Based Learning in Engineering Education; Hong Kong: E2I, Engineering Education Innovation Center, Hong Kong University of Science and Technology; Pakistan: Center for Engineering Education Research, NUST, National University for Science and Technology; South Africa: CREE, Centre for Research in Engineering Education, U of Cape Town; Sweden: Engineering Education Research Group, Linköping U; UK: ESC, Engineering Subject Centre, Higher Education Academy; USA: CELT, Center for Engineering Learning and Teaching, U of Washington; CRLT North, Center for Research on Learning and Teaching, U of Michigan; Faculty Innovation Center, U of Texas-Austin; Engineering Learning Center, U of Wisconsin-Madison; CASEE, Center for the Advancement of Scholarship in Engineering Education, National Academy of Engineering; EEIC, Engineering Education Innovation Center, Ohio State University; CEER, Center for Engineering Education Research, Michigan State University, EECs, Engineering Education Centers in Korea.

- **Engineering Education Degree-granting Departments** — USA: School of Engineering Education, Purdue U; Department of Engineering Education, Virginia Tech; Department of Engineering and Science Education, Clemson U; Department of Engineering and Technology Education, Utah State U; Malaysia: Engineering Education PhD program, Universiti Teknologi Malaysia; India: National Institute for Technical Teacher Training and Research; Mexico: Universidad de las Americas, Puebla.
Engineering education societies...


Forums for dissemination...

Conferences with engineering education research presentations:
- ASEE — Annual Conference, American Society for Engineering Education, see www.asee.org
- AEE — Annual Conference, Australasian Association for Engineering Education, see www.asee.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,
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.


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://personal.cege.umn.edu/~smith/links.html