What IS Rigorous Research in Engineering Education?

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Overview

• Welcome and introductions
• Background about engineering education research
  – Global landscape
  – RREE projects in US
• What IS rigorous research in engineering education
  – Compare and contrast with technical engineering education
  – Global considerations
• Format
  – Interactive
  – “Team” based
Who’s Here

• Introduce yourself
  – Name, Institution, Country, Discipline, etc.
  – Engineering education research experience
  – Expectations/goals for the session
    • What would make this more useful and valuable for you?
Our Characteristics

• Geographic location
• Discipline
• Position – faculty, administrator, researcher, student
• Institutional support for engineering education research
• Engineering education research
  – Involved graduate students
  – Published engineering education articles, conference papers
  – Funding
• Collaborated with social scientists or educators
Workshop Framing

• Workshop is about
  – Deepening understanding of engineering education research
  – Building engineering education research capabilities
  – Identifying and recognizing faculty interested in doing engineering education research

• Workshop is NOT about
  – Pedagogical practice, i.e., “how to teach” seminar
  – Convincing you or your colleagues that good teaching is important
  – Writing engineering education research grant proposals
  – Insisting that all faculty become engineering education researchers
Engineering Education
Levels of Inquiry

• Level 1: Effective Teacher
• Level 2: Scholarly Teacher
• Level 3: Scholarship of Teaching and Learning (SoTL)
• Level 4: Engineering Education Research

Global Landscape
Jack R. Lohmann, Vice Provost and Professor, Georgia Tech, and Editor, Journal of Engineering Education

Understand...
• complex systems
• new materials
• information systems
• multi-disc. design
• global markets
• business practices
• social considerations
• political contexts
• safety
• sustainability
• manufacturability
• reliability
• maintainability
• and...

Be...
• culturally sensitive
• socially aware
• politically astute
• broadly knowledgeable
• lifelong learner
• team player
• effective communicator
• speak foreign languages
• ethical
• innovative
• entrepreneurial
• flexible
• mobile
• and...

Wanted:
The Global Engineer

Can engineering programs really instill all this!?
And if we could...

an international dilemma

- **Who will be there to teach?**
  
  Enrollments are “soft” in developed countries, students see opportunities in other fields

- **How to handle those that are?**
  
  Enrollments are rising rapidly in developing countries, often outstripping their capacity
How should we respond? educational innovation based on R&D

Reform-based model

• **Model:** Innovation based on reflection, experience, intuition
• **Pro:** Generally well-connected to both engineering and teaching practice
• **Con:** Inefficient in discovery, sometimes duplicative, transferability problematic

Research-based model

• **Model:** Innovation based on scholarly educational research
• **Pro:** More efficient in discovery, less duplicative, generally transferable
• **Con:** Can become disconnected from engineering and teaching practice; not many engineering faculty can or will become educational researchers

Research and Development (R&D)-based model

• **Model:** Innovation based educational researchers and practitioners working collaboratively in continuous cycles of educational research and development
• **Pro:** Mutually leverages the “pro’s” of the reform- and research-based models
• **Con:** Jointly diminishes the “con’s”
The challenge
an imbalanced portfolio

- Engineering educational development is a more mature field than engineering educational research...

- ...there is a need to advance the global capacity for engineering educational research to better leverage engineering education development and, thus, accelerate engineering education innovation
Building a global community

communities need support

- Well-defined groups, centers, departments
- Supportive professional organizations and recognitions
- Adequate resources for basic research
- Quality forums for disseminating knowledge

Disclaimer: The following is a very limited set of examples of global developments
Well defined groups, centers, departments...
…supportive professional societies…
...support for basic research...

CAEE
CRLT
CASEE
UCPBL
EERG
EU
UNESCO
CREE
HEI
UICEE

Purdue, VT, Utah St, Clemson
...forums for dissemination

“Advancing the Global Capacity for Engineering Education Research”
(Australia, Brazil, China, Denmark, Hungary, India, Russia, So. Africa, Turkey, USA)

Bottom line: You have a lot of company…and opportunities!
Rigorous Research in Engineering Education (RREE1)

- Summer Workshop - Initial event for year-long project
- Funded by NSF for 3 years, 2004-2006
- About 150 engineering faculty participated
- Presenters and evaluators representing
  - American Society for Engineering Education (ASEE)
  - American Educational Research Association (AERA)
  - Professional and Organizational Development Network in Higher Education (POD)
Rigorous Research in Engineering Education (RREE1)

- Faculty funded by two NSF projects:
  - Conducting Rigorous Research in Engineering Education (NSF DUE-0341127)
  - Strengthening HBCU Engineering Education Research Capacity (NSF HRDF-041194)
- Council of HBCU Engineering Deans
- Center for the Advancement of Scholarship in Engineering Education (CASEE)
- National Academy of Engineering (NAE)
RREE1 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 areas)
- Cultivate the development of a Community of Practice of faculty conducting engineering education research
Engineering Education Research – Closing the Loop

Figure 1.1—Cycle of Knowledge Production and Improvement of Practice
Objectives for today’s Workshop

1. Compare and contrast technical engineering and engineering education research

2. Begin to construct globally-authored definitions of rigorous engineering education research
Engineering Research

What are the guiding principles for rigorous technical research in your engineering discipline?

Technical engineering research can be called rigorous when….

→ Take a few moments individually to list the qualities and characteristics of rigorous research in engineering.

→ As a group, develop a list of research standards in engineering.
Technical (Engineering) Research

- Clear objectives
- Contextual
- Peer reviewed
- Defined methodology
- Theoretical foundation
- Broad based & sharp tipped
- Variables identified
- Sources of error identified
- Repeatable/testable
- Generalizable/transferrable/scalable
- Usually quantitative
- Clear conclusions based on findings
- Believable/credible
- Objective/unbiased
- Builds on former results/former information
- Assumption identified
- Calculations correct
- Method is methodological and appropriate
- Innovative/creative
- Reachable by appropriate audience

- Significance of research contribution
- Continuous improvement of results
- Relevant and impactful
- Advances knowledge
- Cutting edge
- Impactful on society & development of next technology
- Defendable
- Grounded in theory
- Complete and comprehensive both in documentation and research methods
- Novel
- SMART – specific, measurable, achievable, realistic & time-bounded
- Efficiency
- Interdisciplinary
- Short comings and limitations are noted
- Relevant/practical
- Validation – practically and statistically
- Multi-disciplinary
- Sustainable
Engineering Education Research
Differences from engineering research

- More difficult to generalize, e.g., between cultures, laws, surroundings, backgrounds
- Applied to people/social sciences
- Quantitative & qualitative
- Human oriented – softer
- Results & future results more difficult to measure and verify
- More difficult to execute the actions of the process because of unpredictable human interactions
- Ethical consideration
- Depends on research question
- Research needs to be carefully designed from the beginning
- Results are not always quantifiable

- People and bias issues
- Ensuring you have a representative sample (lots of conversations about N)
- Outcomes of research in eng ed is improving the quality of eng ed in terms of pedagogy, epistemology
- More adaptable
- More future oriented
- Need a lot more exposure, e.g., need to go to more sites
- Results are more open to interpretation
- It is credible as opposed to verifiable/repeatable
- Demand should drive an investment of time and effort in research, e.g., faculty demanding new teaching approaches, ABET, NAE, employer, advisory board
What are the guiding principles for rigorous research in engineering education?

Engineering education research can be called rigorous when....

→ Take a few moments individually to list the qualities and characteristics of rigorous engineering education research.

→ As a group, develop a list of research standards in engineering education research.
Guiding Principles for Scientific Research in Education

1. **Question**: pose *significant* question 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 coherent, explicit chain of reasoning
5. **Replicate and generalize** across studies
6. **Disclose** research to encourage professional scrutiny and critique

*National Research Council, 2002*
Reactions & Comparisons

• How does the list generated compare with the NRC Six?
  – Similarities
  – Differences

• Is a global list possible or is the list dependent on the cultural context and research traditions
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
The Craft of Research, 2008

Argument

Claim

Evidence

Method
What’s next?

• Follow-up proposal (RREE2) has been awarded
  – Will include a series of 5 short courses
    • Fundamentals of Educational Research
    • Identifying Theoretical Frameworks
    • Designing Your Research Study
    • Collaborating with Learning and Social Scientists
    • Understanding Qualitative Research
  – Will be available on rreeHUB.org
Acknowledgements

• National Science Foundation
  – (DUE 0341127 & DUE 0817461)

• Norman Fortenberry, NAE/CASEE

• Barney Forsythe, Larry Gruppen, and Ron Miller
  whose slides we have adapted for this presentation.