Studies at the Interface:
Engineering Education as a Field of Research

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Engineering Education as a Field of Research

• Studies at Interfaces
  – Metallurgy
  – Engineering and Education
• Theory-Research-Practice
• Engineering Education Research
  – History & Developments
  – Emerging Landscape
  – Features
Studies at Interfaces

- Theory
- Process Metallurgy
- Learning
- Design
- Scholarship – Engineering Education Research
- Research

Process Metallurgy

- Dissolution Kinetics – liquid-solid interface
- Iron Ore Desliming – solid-solid interface
- Metal-oxide reduction roasting – gas-solid interface
Dissolution Kinetics

- Theory – Governing Equation for Mass Transport
- Research – rotating disk
- Practice – leaching of silver bearing metallic copper

\[ (\nabla c \bullet v) = D \nabla^2 c \]

\[ v_y \frac{dc}{dy} = D \frac{d^2 c}{dy^2} \]

Iron Ore Desliming

- Theory – DLVO \([V(h) = V_A(h) + V_R(h)]\)
- Research – streaming potential
- Practice – recovery of iron from low-grade Fe_2O_3 ores (Selective removal of silicates)
Metal Oxide Reduction Roasting

- Theory – catalyzed gas-solid reactions
  Boudouard Reaction \([\text{CO}_2 + \text{C} = 2\text{CO}]\)
- Research method – thermogravimetric analysis
- Practice – extraction of Ti from FeTiO\(_3\), Al from Al\(_2\)O\(_3\) – bearing minerals

First Teaching Experience

- Practice – Third-year course in metallurgical reactions – thermodynamics and kinetics
Engineering Education

- Practice – Third-year course in metallurgical reactions – thermodynamics and kinetics
- Research – ?
- Theory – ?
University of Minnesota College of Education
Social, Psychological and Philosophical Foundations of Education

- Statistics, Measurement, Research Methodology
- Assessment and Evaluation
- Learning and Cognitive Psychology
- Knowledge Acquisition, Artificial Intelligence, Expert Systems
- Social psychology of learning – student – student interaction

Acquisition of Expertise

- Cognition: Learn from instruction or observation what knowledge and actions are appropriate
- Associative: Practice (with feedback) allowing smooth and accurate performance
- Automaticity: “Compilation” or performance and associative sequences so that they can be done without large amounts of cognitive resources

“The secret of expertise is that there is no secret. It takes at least 10 years of concentrated effort to develop expertise.” Herbert Simon
Paradox of Expertise

• The very knowledge we wish to teach others (as well as the knowledge we wish to represent in computer programs) often turns out to be the knowledge we are least able to talk about.

Expertise Implies:

• a set of cognitive and metacognitive skills
• an organized body of knowledge that is deep and contextualized
• an ability to notice patterns of information in a new situation
• flexibility in retrieving and applying that knowledge to a new problem

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Cooperative Learning

- Research – Randomized Design Field Experiments
- Practice – Formal Teams/Professor’s Role

Theory
Research
Practice

Student – Student Interaction
Lewin’s Contributions

- Founded field of social psychology
- Action Research
- Force-Field analysis
- \( B = f(P,E) \)
- Social Interdependence Theory
- “There is nothing so practical as a good theory”
Cooperative Learning

- Positive Interdependence
- Individual and Group Accountability
- Face-to-Face Promotive Interaction
- Teamwork Skills
- Group Processing

[*First edition 1991]*

Cooperative Learning Research Support


- Over 300 Experimental Studies
- First study conducted in 1924
- High Generalizability
- Multiple Outcomes

Outcomes

1. Achievement and retention
2. Critical thinking and higher-level reasoning
3. Differentiated views of others
4. Accurate understanding of others' perspectives
5. Liking for classmates and teacher
6. Liking for subject areas
7. Teamwork skills

January 2005 March 2007
Small-Group Learning: Meta-analysis


Small-group (predominantly cooperative) learning in postsecondary science, mathematics, engineering, and technology (SMET). 383 reports from 1980 or later, 39 of which met the rigorous inclusion criteria for meta-analysis.

The main effect of small-group learning on achievement, persistence, and attitudes among undergraduates in SMET was significant and positive. Mean effect sizes for achievement, persistence, and attitudes were 0.51, 0.46, and 0.55, respectively.

Cooperative Learning is instruction that involves people working in teams to accomplish a common goal, under conditions that involve both positive interdependence (all members must cooperate to complete the task) and individual and group accountability (each member is accountable for the complete final outcome).

Key Concepts

• Positive Interdependence
• Individual and Group Accountability
• Face-to-Face Promotive Interaction
• Teamwork Skills
• Group Processing

Active and Cooperative Learning

Calls for evidence-based promising practices

Book Ends on a Class Session

Thinking Together: Collaborative Learning in the Sciences – Harvard University – Derek Bok Center – www.fas.harvard.edu/~bok_cen/
Problem-Based Cooperative Learning

At M.I.T., Large Lectures Are Going the Way of the Blackboard


http://web.mit.edu/edtech/casestudies/teal.html#video
Cooperative Learning Adopted
The American College Teacher:
National Norms for 2007-2008

<table>
<thead>
<tr>
<th>Methods Used in “All” or “Most”</th>
<th>All – 2005</th>
<th>All – 2008</th>
<th>Assistant - 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative Learning</td>
<td>48</td>
<td>59</td>
<td>66</td>
</tr>
<tr>
<td>Group Projects</td>
<td>33</td>
<td>36</td>
<td>61</td>
</tr>
<tr>
<td>Grading on a curve</td>
<td>19</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Term/research papers</td>
<td>35</td>
<td>44</td>
<td>47</td>
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http://www.heri.ucla.edu/index.php
First Course Design Experience
UMN – Institute of Technology

• Thinking Like an Engineer
• Problem Identification
• Problem Formulation
• Problem Representation
• Problem Solving

Problem-Based Learning

*Based on First Year Engineering course – Problem-based cooperative learning approach published in 1990.
It could well be that faculty members of the twenty-first century college or university will find it necessary to set aside their roles as teachers and instead become designers of learning experiences, processes, and environments.

James Duderstadt, 1999 [Nuclear Engineering Professor; Dean, Provost and President of the University of Michigan]

...objectives for engineering practice, research, and education:

To adopt a systemic, research-based approach to innovation and continuous improvement of engineering education, recognizing the importance of diverse approaches—albeit characterized by quality and rigor—to serve the highly diverse technology needs of our society

Engineering Education Research

Colleges and universities should endorse research in engineering education as a valued and rewarded activity for engineering faculty and should develop new standards for faculty qualifications.

Scholarship Reconsidered: Priorities of the Professoriate Ernest L. Boyer

- The Scholarship of Discovery, research that increases the storehouse of new knowledge within the disciplines;
- The Scholarship of Integration, including efforts by faculty to explore the connectedness of knowledge within and across disciplines, and thereby bring new insights to original research;
- The Scholarship of Application, which leads faculty to explore how knowledge can be applied to consequential problems in service to the community and society; and
- The Scholarship of Teaching, which views teaching not as a routine task, but as perhaps the highest form of scholarly enterprise, involving the constant interplay of teaching and learning.
Levels of Engineering Education Inquiry

- **Level 0** Teacher
  - Teach as taught ("distal pedagogy")
- **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

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

<table>
<thead>
<tr>
<th>Theory</th>
<th>Research that makes a difference . . . in theory and practice</th>
</tr>
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<tbody>
<tr>
<td>(study grounded in theory/conceptual framework)</td>
<td>(appropriate design and methodology)</td>
</tr>
<tr>
<td>Practice</td>
<td>(implications for teaching)</td>
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http://inside.mines.edu/research/cee/ND.htm
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*

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Research can be inspired by ...

<table>
<thead>
<tr>
<th>Understanding (Basic)</th>
<th>Use (Applied)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Pure basic research (Bohr)</td>
</tr>
<tr>
<td>Yes</td>
<td>Use-inspired basic research (Pasteur)</td>
</tr>
<tr>
<td>Pure applied research (Edison)</td>
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RREE2

Follow-up proposal has been awarded (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

*To be recorded and posted on the CLEERhub.org
Status of RREE Project

- EER workshops and EER - JEE Collaboration
  - Fundamentals of Educational Research
    - ASEE 2010
    - FIE 2010
  - Selecting Conceptual Frameworks for Engineering Education Research
    - RCEE/UTM Malaysia 2010
    - ASEE 2010
  - Understanding Qualitative Research
    - FIE 2010
- Collaboratory for Engineering Education Research (CLEERhub.org)

http://cleerhub.org
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 Teaching and Learning Centers — Australia: UICEE, UNESCO International Centre for Engineering Education; Denmark: UCPBLEE, UNESCO Chair in Problem Based Learning in Engineering Education; 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.

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
- 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/
Engineering Education Research Networking Session
Connecting Engineering Education Research Programs from Around the World

sponsored by the ASEE International Division
in partnership with Rigorous Research in Engineering Education Initiative CLEERhub.org
And the Journal of Engineering Education

ASEE Annual Conference – June 22, 2010 – Session 2123

Facilitated By

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ASEE 2010 - EER PhD Program Briefings

- Utah State University - Kurt Becker
- Purdue University - David Radcliffe & Robin Adams
- Universidad de las Americas, Puebla, Mexico - Enrique Palou
- Virginia Tech - Maura Borrego
- Universiti Teknologi Malaysia - Zaini Ujang
- Clemson University - Lisa Benson
- NITTTRs - India - R. Natarajan
- Arizona State University - Tirupalavanam Ganesh & Chell Roberts
- University of Washington - Cindy Atman
- Ohio State University - Lisa Abrams
- Carnegie Mellon University - Paul Steif
- University of Michigan - Cindy Finelli
- Washington State University - Denny Davis
- University of Georgia - Nadia Kellam & Joachim Walther
- Michigan State University - Jon Sticklen
- University of Colorado - Boulder - Daria Kotys-Schwartz

Session slides and links to programs posted to CLEERhub.org
CRITERIA FOR A FIELD

1. **Structural Criteria**
   1. Academic recognition
   2. Research journals
   3. Professional associations
   4. Research conferences
   5. Research centers
   6. Research training

2. **Intra-Research Criteria**
   1. Scientific knowledge
   2. Asking questions
   3. Conceptual and theoretical development
   4. Research methodologies
   5. Progression
   6. Model publications
   7. Seminal publications

3. **Outcome Criteria**
   1. Implications for practice
Maya Lin *Boundaries*

*I feel I exist on the boundaries.*
Acknowledgement

• We acknowledge the National Science Foundation for funding Karl Smith & Ruth Streveler's participation (DUE 0817461)
  - COLLABORATIVE RESEARCH: Expanding and sustaining research capacity in engineering and technology education: Building on successful programs for faculty and graduate students
• And the University of Florida for hosting this seminar

Thank you!

An e-copy of this presentation will be posted to: http://CLEERhub.org

University of Florida – Materials Science and Engineering – February 1, 2011

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