Advancing the Practice of Engineering Education

Karl A. Smith
Engineering Education – Purdue University
STEM Education Center/Civil Eng – University of Minnesota
ksmith@umn.edu - http://www.ce.umn.edu/~smith/

South African Society for Engineering Education

Stellenbosch, South Africa
10-12 August, 2011

Engineering

A principal feature of the engineering method is advancing the state of the art (Koen, 2009).

The engineering method is the use of heuristics to cause the best change in a poorly understood situation within the available resources – (Koen, 1971, 2000)

The engineering method is design under constraints – Wm. Wulf, Past President, U.S. National Academy of Engineering

Questions Shaping the Keynote

- How do we embrace engineering principles in engineering education?
  - How do we cultivate innovative practices in engineering education
- How do we close the loop between research and practice?
  - What is the role of engineering education research?
- What is RREE, Rigorous Research in Engineering Education?
  - How is it similar and different from traditional engineering research and practice?

Engineering Education Research & Innovation – Karl Smith

Research

•Process Metallurgy 1970 -1992
•Learning ~1974
•Design ~1995
•Engineering Education Research & Innovation ~ 2000

Innovation – Cooperative Learning

•Need identified ~1974
•Introduced ~1976
•FIE conference 1981
•*JEE* paper 1981
•Research book 1991
•Practice handbook 1991
•*Change* paper 1998
•*Teamwork and project management* 2000
•*JEE* paper 2005

National Academy of Engineering - Frontiers of Engineering Education Symposium - December 13-16, 2010 - Slides PDF [Smith-NAE-FOEE-HPL-UbD-12-10-v8.pdf]

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

$$(\nabla c \bullet \underline{v}) = D\nabla^2 c$$

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

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)

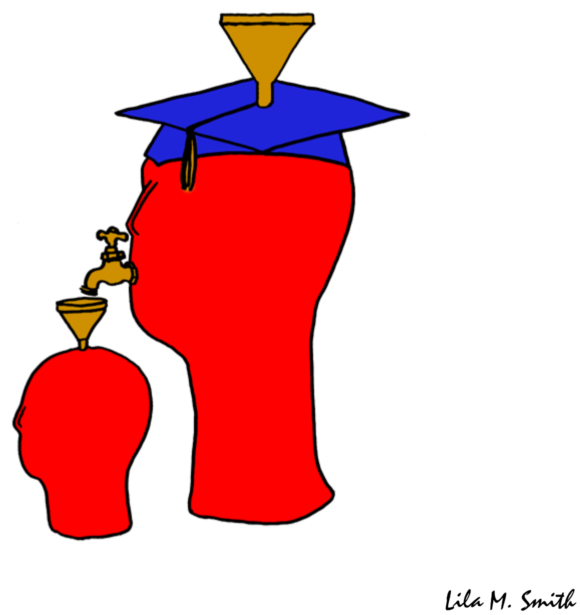
Metal Oxide Reduction Roasting

- Theory – catalyzed gas-solid reactions

  Boudouard Reaction [$CO_2 + C = 2CO$]
- Research method – thermogravimetric analysis
- Practice – extraction of Ti from $FeTiO_3$, Al from Al_2O_3 – bearing minerals

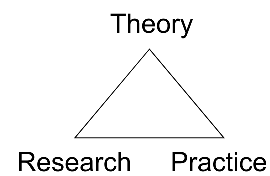
First Teaching Experience

- 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

Fitts P, & Posner MI. Human Performance. Belmont, CA: Brooks/Cole, 1967.

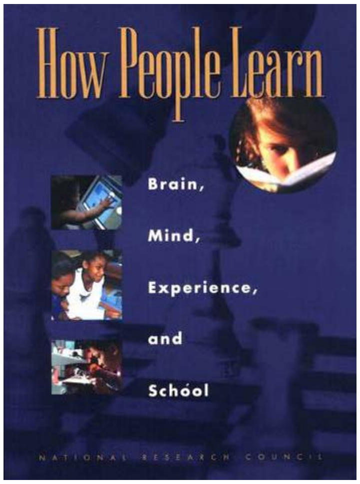
- Cognition: Learn from instruction or observation what knowledge and actions are appropriate
- Associative: Practice (with feedback) allowing smooth and accurate performance
- Automaticity: “Compilation” or performance and associative sequences so that they can be done without large amounts of cognitive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

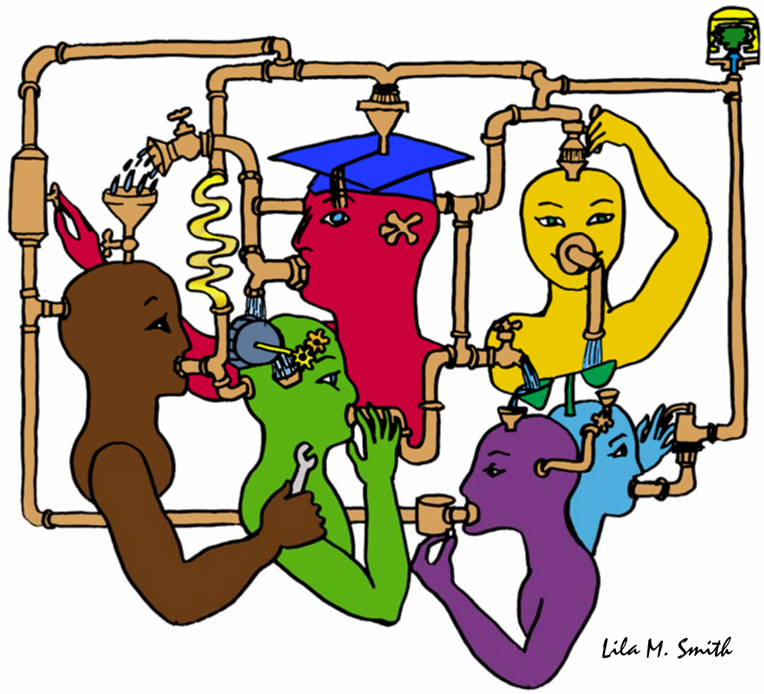


- a set of cognitive and metacognitive skills
- an organized body of knowledge that is deep and contextualized
- an ability to notice patterns of information in a new situation
- flexibility in retrieving and applying that knowledge to a new problem

Bransford, Brown & Cocking. 1999. *How people learn.* National Academy Press.

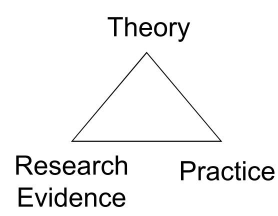
University of Minnesota College of Education
Social, Psychological and Philosophical
Foundations of Education

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



Cooperative Learning

- Theory – Social Interdependence – Lewin – Deutsch – Johnson & Johnson
- Research – Randomized Design Field Experiments
- Practice – Formal Teams/Professor's Role



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"

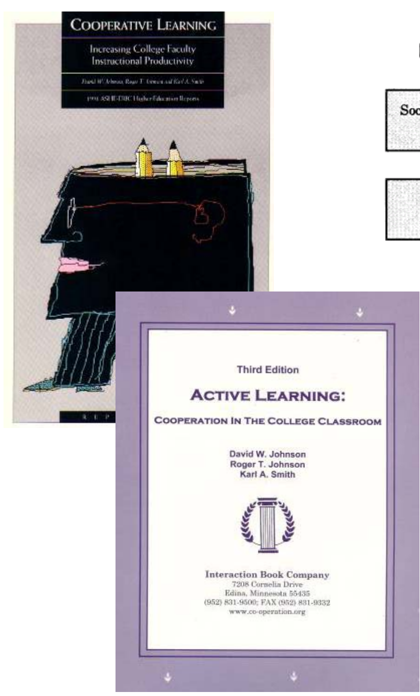
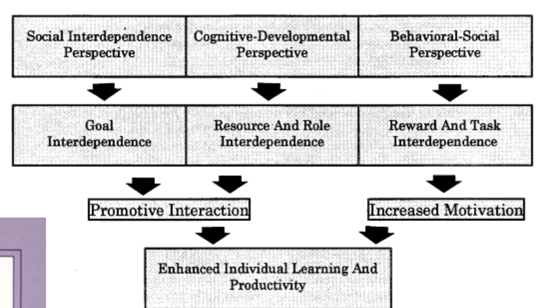


Figure A.1 A General Theoretical Framework



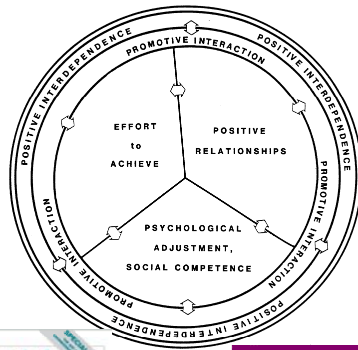
Cooperative Learning
•Positive Interdependence
•Individual and Group Accountability
•Face-to-Face Promotive Interaction
•Teamwork Skills
•Group Processing

[*First edition 1991]

Cooperative Learning Research Support

Johnson, D.W., Johnson, R.T., & Smith, K.A. 1998. Cooperative learning returns to college: What evidence is there that it works? *Change*, *30* (4), 26-35.

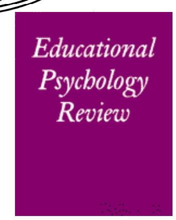
- Over 300 Experimental Studies
- First study conducted in 1924
- High Generalizability
- Multiple Outcomes



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

Springer, L., Stanne, M. E., & Donovan, S. 1999. Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. Review of Educational Research, 69(1), 21-52.

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).

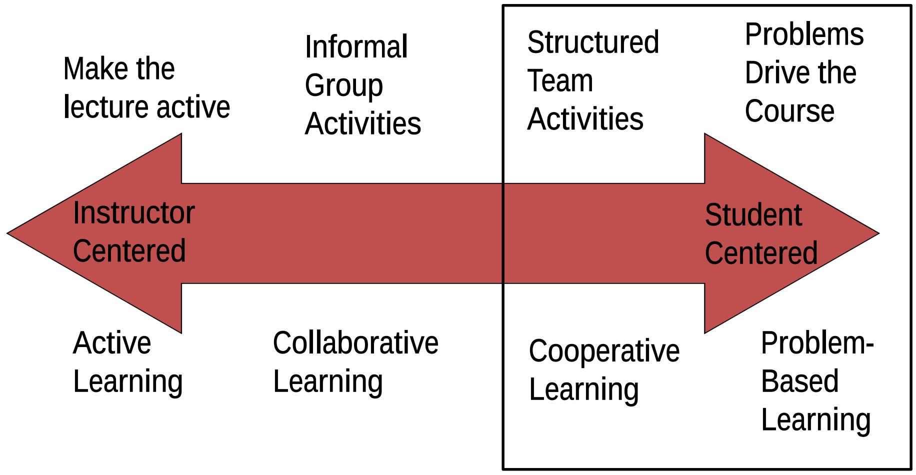
Key Concepts

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

http://www.ce.umn.edu/~smith/docs/Smith-CL%20Handout%2008.pdf

Pedagogies of Engagement

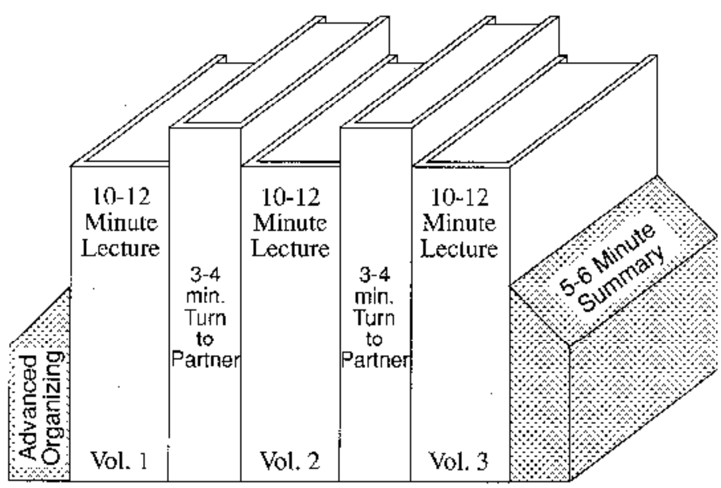
The Active Learning Continuum



Prince, M. (2010). NAE FOEE

My work is situated here – Cooperative Learning & Challenge-Based Learning

Book Ends on a Class Session



Problem-Based Cooperative Learning

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

Jodi Hilton for The New York Times

The Massachusetts Institute of Technology has changed the way it offers some introductory classes. Prof. Gabriella Sciolla at a class on electricity and magnetism.

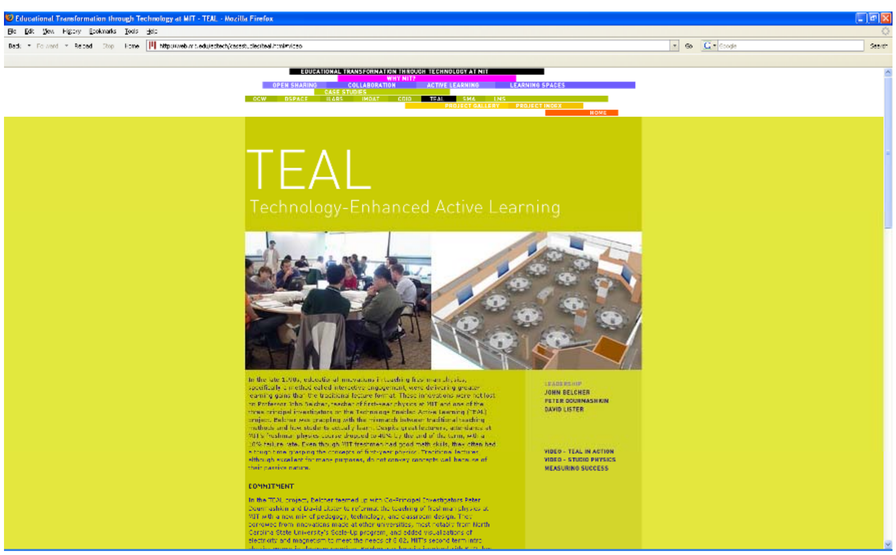
By SARA RIMER
Published: January 12, 2009

COMMENTS (00)
E-MAIL
PRINT
SINGLE PAGE

CAMBRIDGE, Mass. — For as long as anyone can remember, introductory physics at the Massachusetts Institute of Technology was taught in a vast windowless amphitheater known by its number,

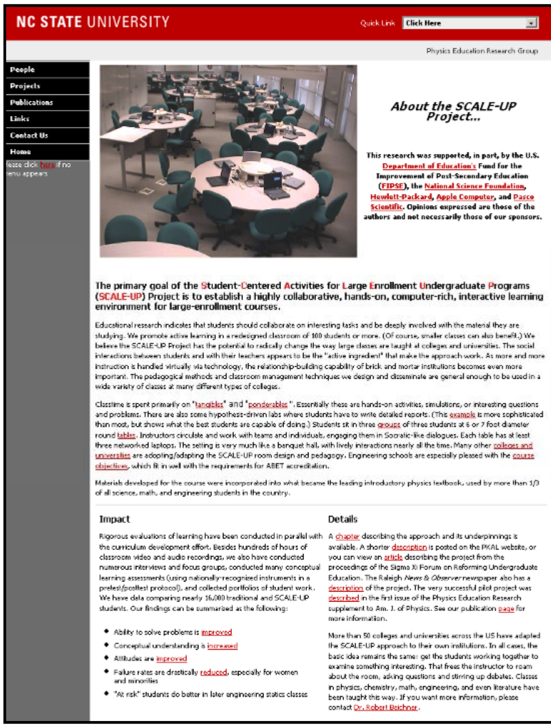
January 13, 2009—New York Times – http://www.nytimes.com/2009/01/13/us/13physics.html?em

27



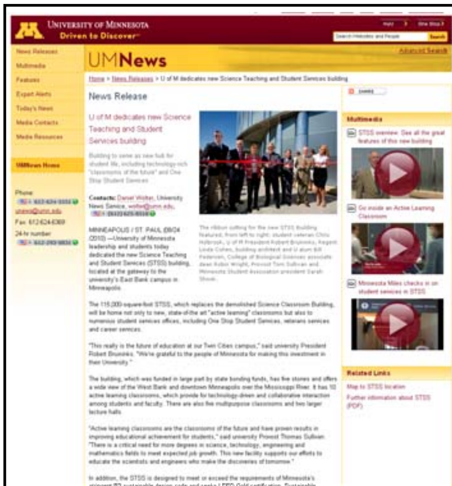
http://web.mit.edu/edtech/casestudies/teal.html#video

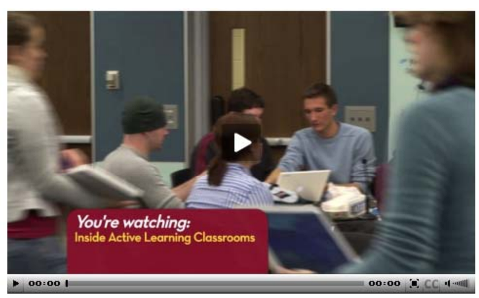
28



http://www.ncsu.edu/PER/scaleup.html

29





http://mediamill.cla.umn.edu/mediamill/embed/78755

http://www1.umn.edu/news/news-releases/2010/UR_CONTENT_248261.html

30

PROBLEM-BASED LEARNING

- UD PBL articles and books
- UD PBL in the news
- Sample PBL problems
- UD PBL courses and syllabi
- PBL Clearinghouse
- PBL Conferences and Other PBL sites
- Institute for Transforming Undergraduate Education
- Other related UD sites

"How can I get my students to think?" is a question asked by many faculty, regardless of their disciplines. Problem-based learning (PBL) is an instructional method that challenges students to "learn to learn," working cooperatively in groups to seek solutions to real world problems. These problems are used to engage students' curiosity and initiate learning the subject matter. PBL prepares students to think critically and analytically, and to find and use appropriate learning resources. -- *Barbara Duch*

PBL2002:
A Pathway to Better Learning

Recipient of 1999 Hesburgh Certificate of Excellence

Please direct comments, suggestions, or requests to ud-pbl@udel.edu.
"http://www.udel.edu/pbl/"
Last updated March 13, 2004.

http://www.udel.edu/pbl/

Cooperative Learning Adopted

The American College Teacher:

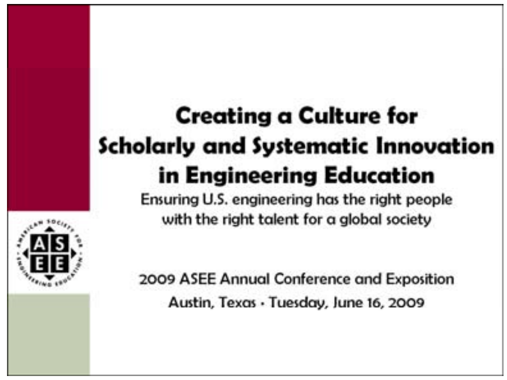
National Norms for 2007-2008

Methods Used in "All" or "Most"	All – 2005	All – 2008	Assistant - 2008
Cooperative Learning	48	59	66
Group Projects	33	36	61
Grading on a curve	19	17	14
Term/research papers	35	44	47

http://www.heri.ucla.edu/index.php

32

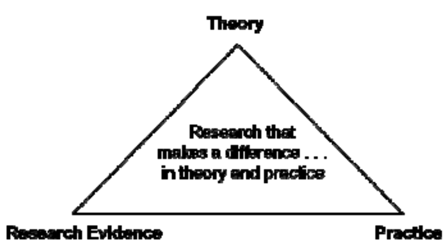
Celebration of Two Major ASEE Milestones

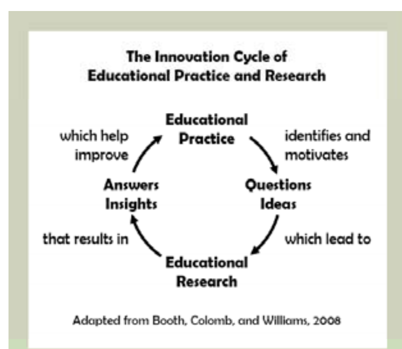


2011 ASEE Annual Conference and Exposition

Vancouver, British Columbia • Monday, June 27, 2011

One BIG Idea; Two Perspectives





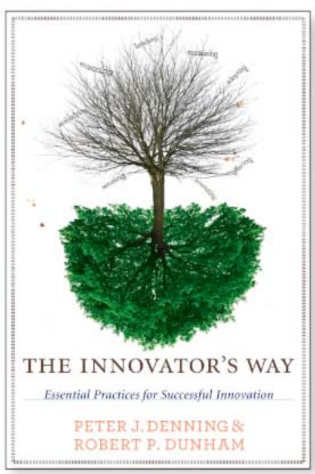
Jamieson & Lohmann (2009)

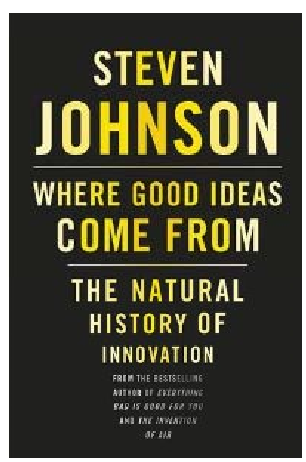
Engineering Education Innovation

ASEE Main Plenary, 8:45 a.m. – 10:15 a.m.
Vancouver International Conference Centre, West Ballroom CD
Expected to draw over 2,000 attendees, this year's plenary features Karl A. Smith, Cooperative Learning Professor of Engineering Education at Purdue University and Morse–Alumni Distinguished Teaching Professor & Professor of Civil Engineering at the University of Minnesota.
Smith has been at the University of Minnesota since 1972 and has been active in ASEE since he became a member in 1973. For the past five years, he has been helping start the engineering education Ph.D. program at Purdue University. He is a Fellow of the American Society for Engineering Education and past Chair of the Educational Research and Methods Division. He has worked with thousands of faculty all over the world on pedagogies of engagement, especially cooperative learning, problem-based learning, and constructive controversy.
On the occasion of the 100th anniversary of the Journal of Engineering Education and the release of ASEE's Phase II report *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education* (Jamieson/Lohmann report), the plenary will celebrate these milestones and demonstrate rich, mutual interdependences between practice and inquiry into teaching and learning in engineering education. Depth and range of the plenary will energize the audience and reflects expertise and interests of conference participants. One of ASEE's premier educators and researchers, Smith will draw upon our roots in scholarship to set the stage and weave the transitions for six highlighted topics selected for their broad appeal across established, evolving, and emerging practices in engineering education.

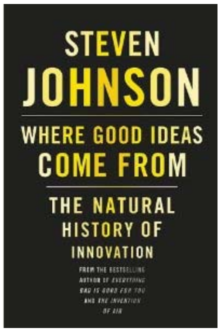
Highlights from Monday:

Monday's **Main Plenary** by Karl A. Smith, Cooperative Learning Professor of Engineering Education at Purdue University and Morse–Alumni Distinguished Teaching Professor & Professor of Civil Engineering at the University of Minnesota, focused on six highlighted topics (presented by six different educators) selected for their broad appeal across established, evolving, and emerging practices in engineering education.

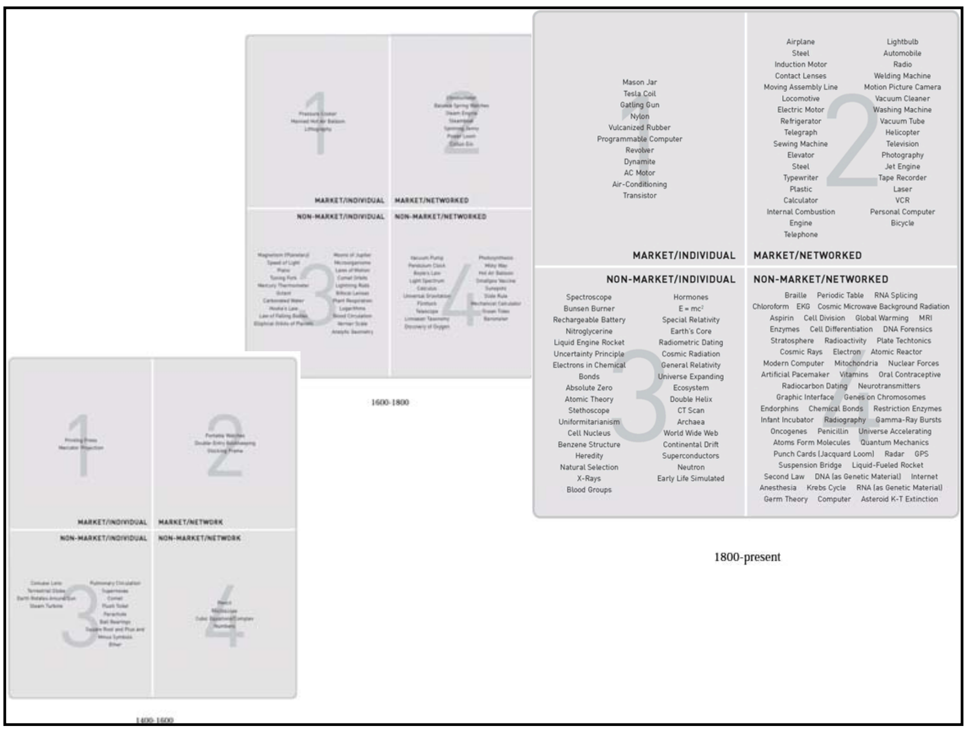




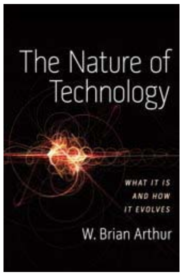
Innovation is the adoption
of a new practice in a community
- Denning & Dunham (2010)



1. What is the distribution of innovations?
2. Did it change over time? If so, how?
3. Where does **your** innovation fit?



Technology



Three definitions of technology (Arthur, 2009)

1. A means to fulfill a human purpose
2. An assemblage of practices and components
3. The entire collection of devices and engineering practices available to a culture

Three fundamental principles (Arthur, 2009):

1. All technologies are combinations
2. Each component of technology is itself in miniature a technology
3. All technologies harness and exploit some effect or phenomena, usually several

Definitions

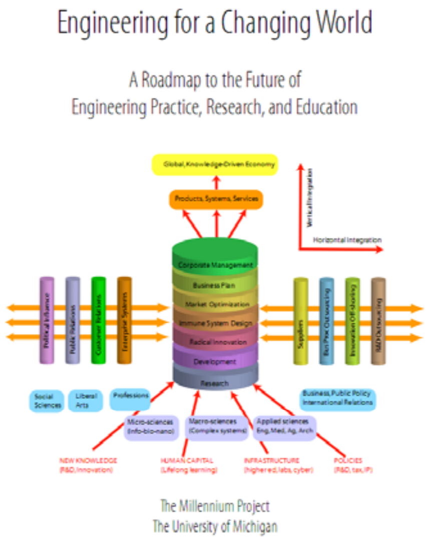
- Technology – OED
  - τεχυολοία
  - systematic treatment of art, craft
- Engineering – OED
  - The action of the verb ENGINEER; the work done by, or the profession of, an engineer.
- Smith – OED
  - One who works in iron or other metal
  - Original sense – craftsman, skilled worker in metal, wood or other material

Engineering in Popular Media

- "Houston, we've got a problem." Apollo 13
- MacGyver?
- Myth Busters?
- Petroski

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

http://milproj.ummu.umich.edu/publications/EngFlex%20report/download/EngFlex%20Report.pdf

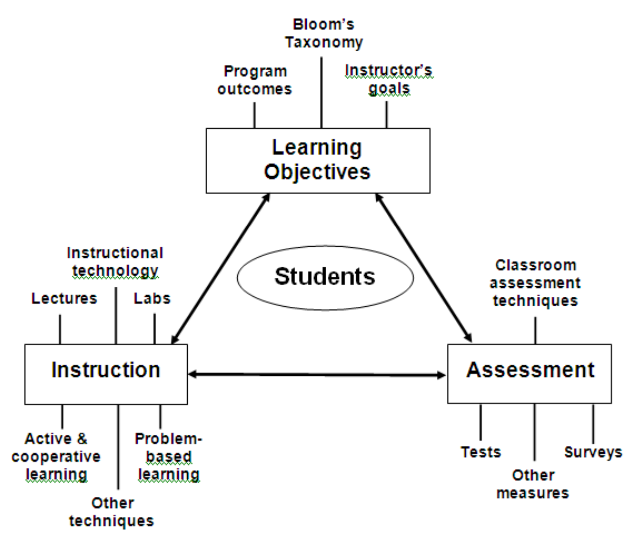
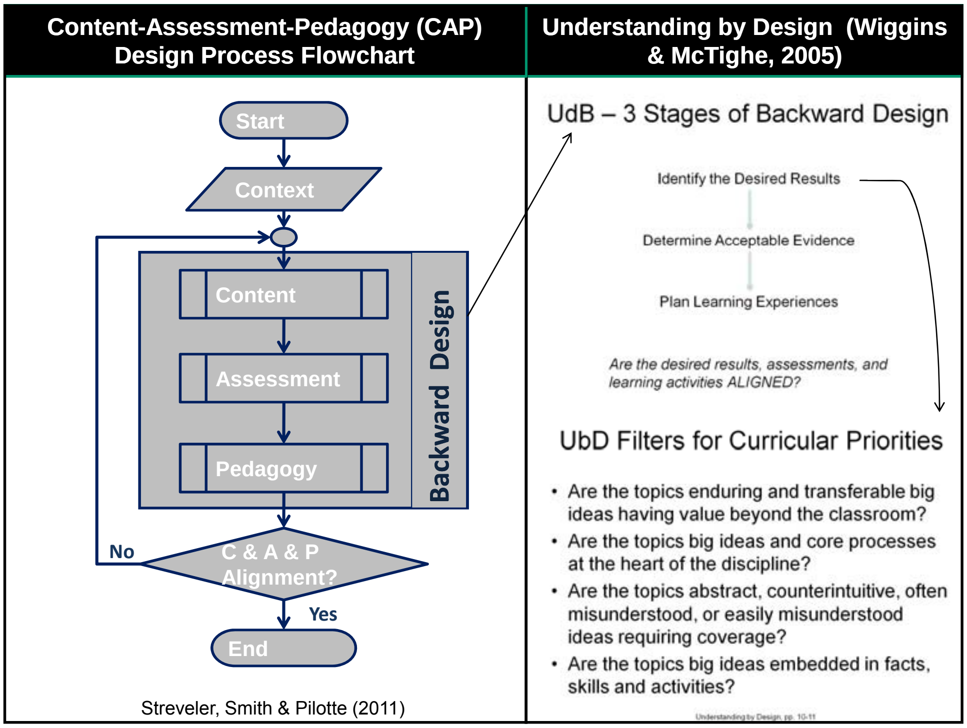
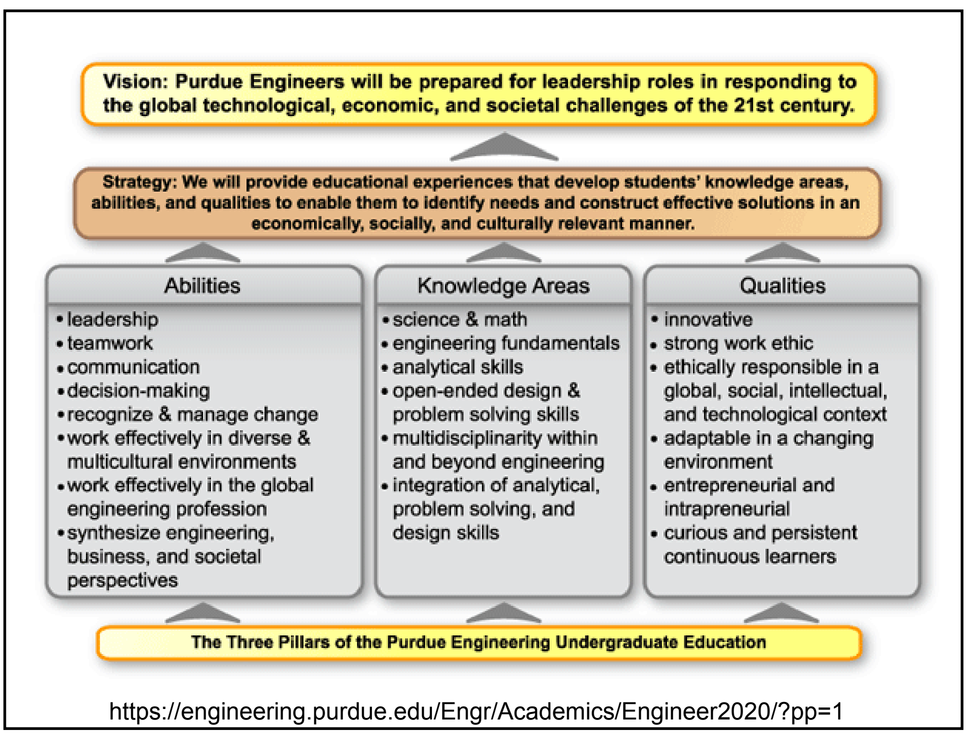


Figure 1. Elements of Course Design*

*R.M. Felder and R. Brent. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *J. Engr. Education, 92*(1), 7–25.

44


Content-Assessment-Pedagogy (CAP) Design Process Flowchart
Understanding by Design (Wiggins & McTighe, 2005)
Start
Context
Content
Assessment
Pedagogy
Backward Design
No
C & A & P Alignment?
Yes
End
Streveler, Smith & Pilotte (2011)
UdB – 3 Stages of Backward Design
Identify the Desired Results
Determine Acceptable Evidence
Plan Learning Experiences
Are the desired results, assessments, and learning activities ALIGNED?
UbD Filters for Curricular Priorities
• Are the topics enduring and transferable big ideas having value beyond the classroom?
• Are the topics big ideas and core processes at the heart of the discipline?
• Are the topics abstract, counterintuitive, often misunderstood, or easily misunderstood ideas requiring coverage?
• Are the topics big ideas embedded in facts, skills and activities?


Vision: Purdue Engineers will be prepared for leadership roles in responding to the global technological, economic, and societal challenges of the 21st century.
Strategy: We will provide educational experiences that develop students' knowledge areas, abilities, and qualities to enable them to identify needs and construct effective solutions in an economically, socially, and culturally relevant manner.
Abilities
• leadership
• teamwork
• communication
• decision-making
• recognize & manage change
• work effectively in diverse & multicultural environments
• work effectively in the global engineering profession
• synthesize engineering, business, and societal perspectives
Knowledge Areas
• science & math
• engineering fundamentals
• analytical skills
• open-ended design & problem solving skills
• multidisciplinarity within and beyond engineering
• integration of analytical, problem solving, and design skills
Qualities
• innovative
• strong work ethic
• ethically responsible in a global, social, intellectual, and technological context
• adaptable in a changing environment
• entrepreneurial and intrapreneurial
• curious and persistent continuous learners
The Three Pillars of the Purdue Engineering Undergraduate Education
https://engineering.purdue.edu/Engr/Academics/Engineer2020/?pp=1

Desired Attributes of a Global Engineer*

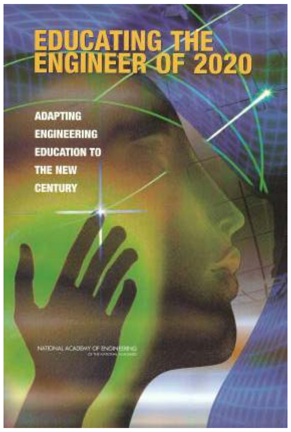
- A multidisciplinary, systems perspective, along with a product focus
- **An awareness of the boundaries of one's knowledge, along with an appreciation for other areas of knowledge and their interrelatedness with one's own expertise**
- **An awareness of and strong appreciation for other cultures and their diversity, their distinctiveness, and their inherent value**
- A strong commitment to team work, including extensive experience with and understanding of team dynamics
- High ethical standards (honesty, sense of personal and social responsibility, fairness, etc)
- An ability to think both critically and creatively, in both independent and cooperative modes

*A Manifesto for Global Engineering Education, Summary Report of the Engineering Futures Conference, January 22-23, 1997. The Boeing Company & Rensselaer Polytechnic Institute.

Successful Attributes for the Engineer of 2020

- Possess strong analytical skills
- Exhibit practical ingenuity; posses creativity
- Good communication skills with multiple stakeholders
- Business and management skills; Leadership abilities
- High ethical standards and a strong sense of professionalism
- Dynamic/agile/resilient/flexible
- Lifelong learners

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.

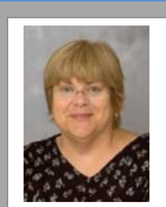
Getting Started in Engineering Education Research

Fundamentals of Engineering Education Research

sponsored by the
ASEE Educational Research and Methods Division

in partnership with
Rigorous Research in Engineering Education Initiative
CLEERhub.org
And the *Journal of Engineering Education*

ASEE Annual Conference – June 20, 2010 – Session 0230



Ruth A.Streveler
Purdue University

Karl A. Smith
Purdue University and
University of Minnesota

Levels of Engineering Education Inquiry

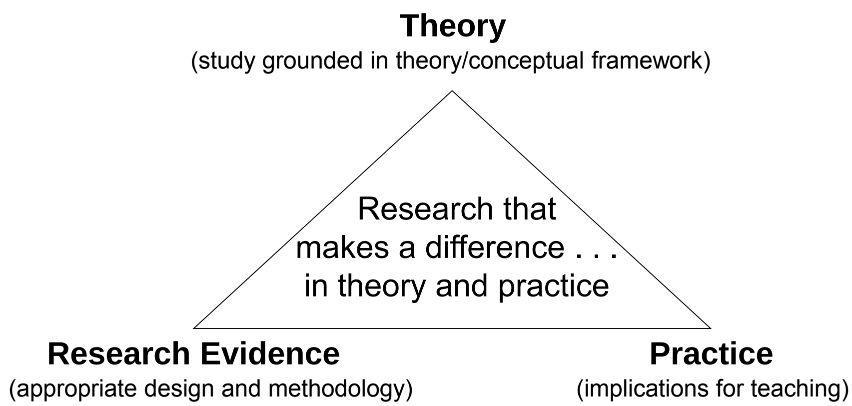
- **Level 0** Teacher
  - Teach as taught ("distal pedagogy")
- **Level 1** Effective Teacher
  - Teach using accepted teaching theories and practices
- **Level 2** Scholarly Teacher
  - Assesses performance and makes improvements
- **Level 3** Scholar of Teaching and Learning
  - Engages in educational experimentation, shares results
- **Level 4** Engineering Education Researcher
  - Conducts educational research, publishes archival papers

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.

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



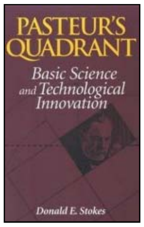
http://inside.mines.edu/research/cee/ND.htm

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

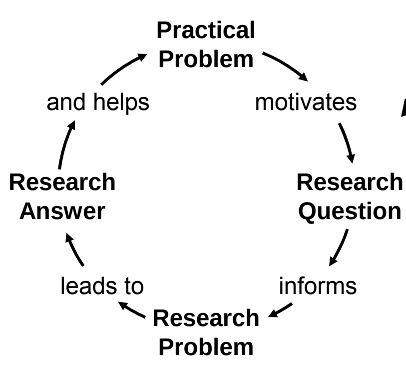
Research can be inspired by ...



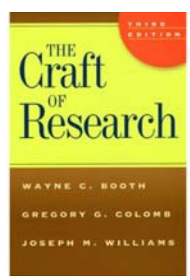
Understanding (Basic)	Use (Applied): No	Use (Applied): Yes
Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No		Pure applied research (Edison)

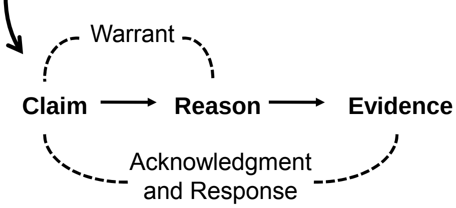
Source: Stokes, D. 1997. Pasteur's quadrant: Basic science and technological innovation. Washington, DC: Brookings Institution.

Research Process



Research Process





Research Reasoning

RREE2

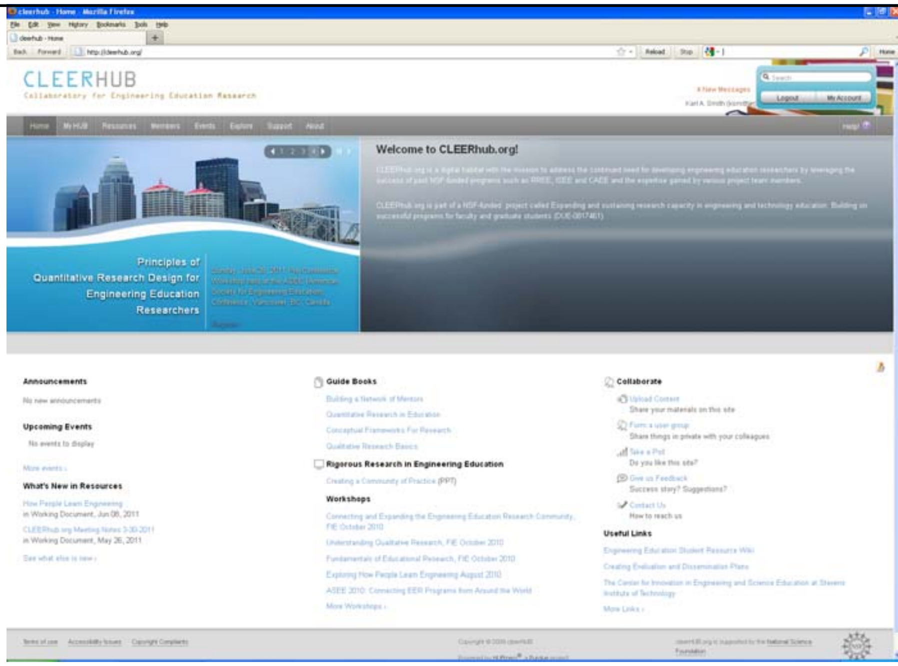
Follow-up proposal has been awarded (RREE2)

- 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 - SASEE 2011**
  - **Selecting Conceptual Frameworks for Engineering Education Research**
    - **RCEE/UTM Malaysia 2010 - ASEE 2010**
  - **Understanding Qualitative Research**
    - **FIE 2010**
  - **Designing Your Research Study**
    - **ASEE 2011**
- **Collaboratory for Engineering Education Research (CLEERhub.org)**



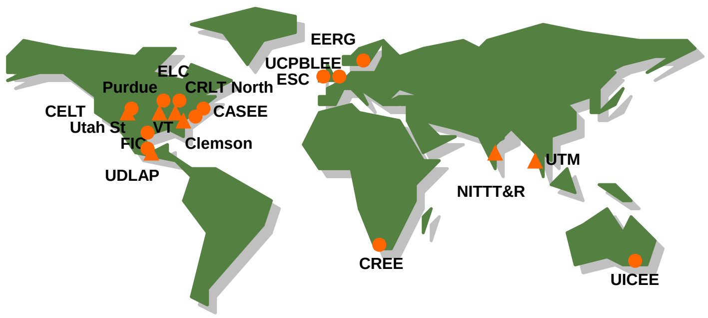
http://cleerhub.org

An <u>emerging</u> 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.

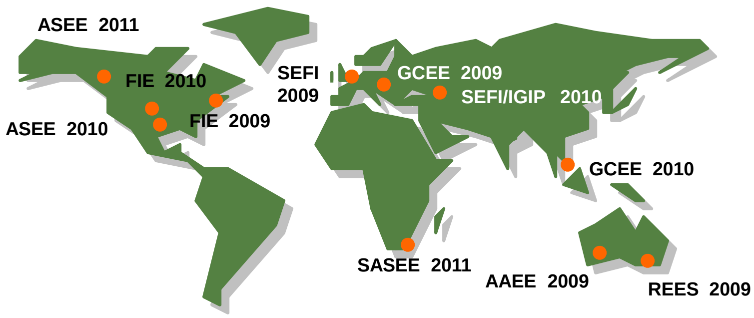
Engineering Education Degree-granting Departments — USA: School of Engineering Education, Purdue U; Department of Engineering Education, Virginia Tech; Department of Engineering and Science Education, Clemson U; Department of Engineering and Technology Education, Utah State U; Malaysia: Engineering Education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

Engineering education societies...

Societies with Engineering Education Research Groups — ASEE, American Society for Engineering Education, Educational Research Methods Division; SEFI, Société Européenne pour la Formation des Ingénieurs (European Society for Engineering Education), Engineering Education Research Working Group; Australasian Association for Engineering Education, Engineering Education Research Working Group; Community of Engineering Education Research Scholars, Latin America and Caribbean Consortium for Engineering Institutions

Societies with Engineering Education Research Interests — Indian Society for Technical Education, Latin American and Caribbean Consortium of Engineering Institutions, Asociación Nacional de Facultades y Escuelas de Ingeniería (National Association of Engineering Colleges and Schools in Mexico), Internationale Gesellschaft für Ingenieurpädagogik (International Society for Engineering Education), International Federation of Engineering Education Societies, South African Engineering Education Association (SASEE)

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
- **FIE** — Frontiers in Education, sponsored by ERM/ASEE, IEEE Education Society and Computer Society, /fie-conference.org/erm
- **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,

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

Karl A. Smith
Purdue University and
University of Minnesota

Ruth A. Streveler
Purdue University

Jack Lohmann
Georgia Tech

Satish Udpa
Michigan State University

Hans Hoyer
ASEE

Stephanie Eng
ASEE

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

Thank you!

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

South African Society for Engineering Education (SASEE) – August 10, 2011

ksmith@umn.edu