Studies at the Interface: Engineering Education Research and Engineering Education Innovation

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Civil Engineering - University of Minnesota
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Vanderbilt University
STEM Education – CIRTL
April 12, 2011

Engineering Education Research & Innovation

Research
- •Process Metallurgy
- •Learning
- •Design
- •Engineering Education Research & Innovation

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

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

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

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)

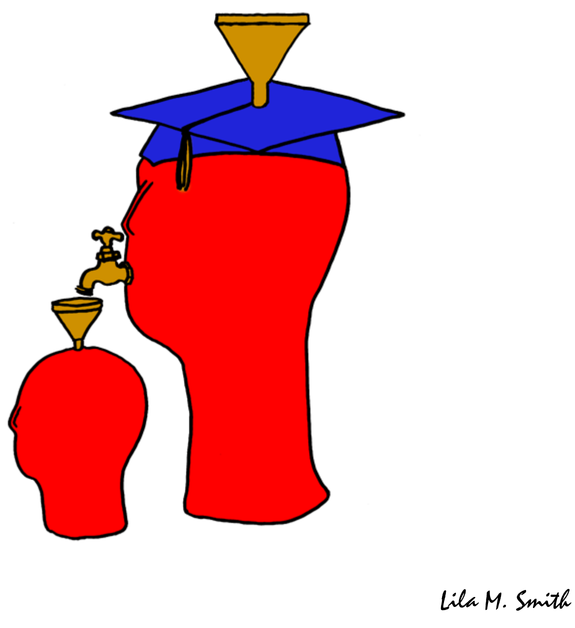
Metal Oxide Reduction Roasting

- 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

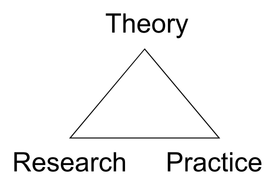
First Teaching Experience

- 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.

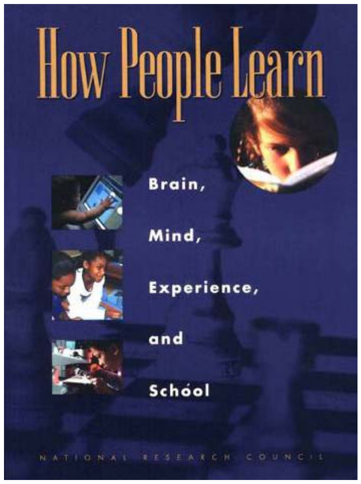
- Cognition: Learn from instruction or observation what knowledge and actions are appropriate
- Associative: Practice (with feedback) allowing smooth and accurate performance
- Automaticity: “Compilation” or performance and associative sequences so that they can be done without large amounts of cognitive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

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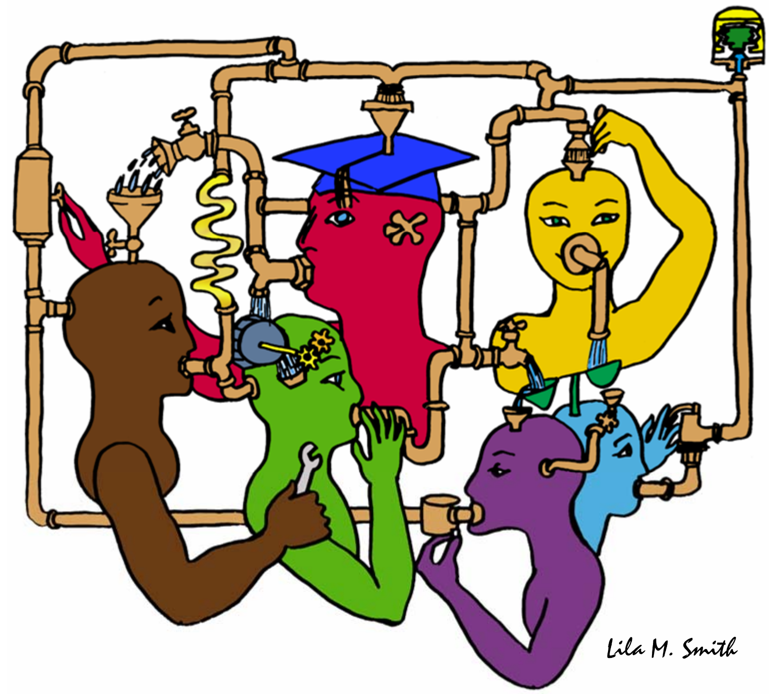
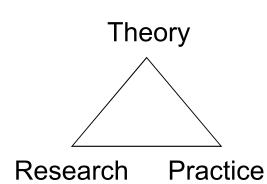


Cooperative Learning

- 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"

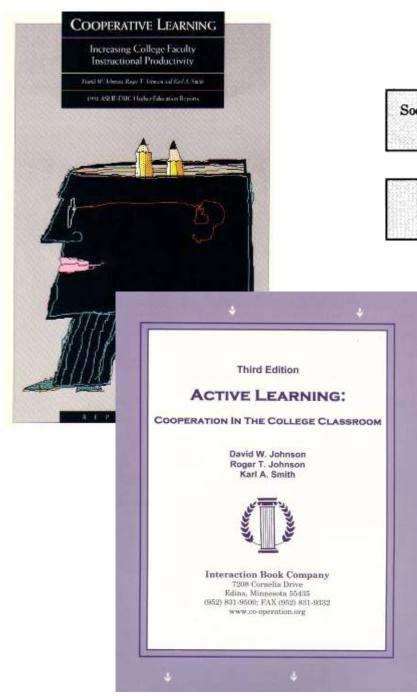
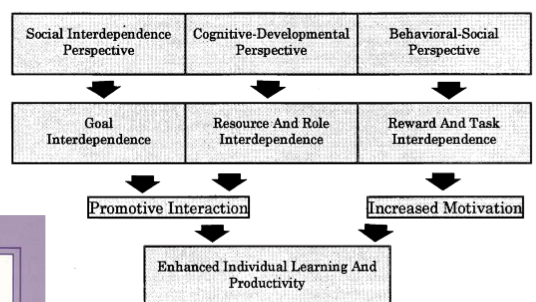


Figure A.1 A General Theoretical Framework



Cooperative Learning

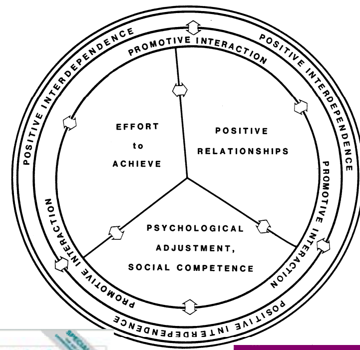
- Positive Interdependence
- Individual and Group Accountability
- Face-to-Face Promotive Interaction
- Teamwork Skills
- Group Processing

[*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.

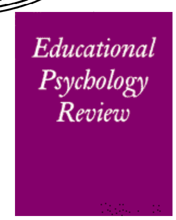
- Over 300 Experimental Studies
- First study conducted in 1924
- High Generalizability
- Multiple Outcomes



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

Active and Cooperative Learning

EDUCATION

Farewell, Lecture?

Eric Mazur

A physics professor describes his evolution from lecturing to dynamically engaging students during class and improving how they learn.

Discussions of education are generally predicated on the assumption that we know what education is. I hope to convince you otherwise by recounting some of my own experiences. When I started teaching introductory physics to undergraduates at Harvard University, I never asked myself how I would educate my students. I did what my teachers had done—I lectured. I thought that was how one learns. Look around anywhere in the world and you'll find lecture halls filled with students and, at the front, an instructor. This approach to education has not changed since before the Renaissance and the birth of scientific inquiry. Early in my career I received the first hints that something was wrong with teaching in this manner, but I had ignored it. Sometimes it's hard to face reality.

When I started teaching, I prepared lecture notes and then taught from them. Because my lectures deviated from the textbook, I provided students with copies of these lecture notes. The infuriating result was that on my end-of-semester evaluations—which were quite good otherwise—a number of students complained that I was "lecturing straight from (his) lecture notes." What was I supposed to do? Develop a set of lecture notes different from the ones I handed out? I decided to ignore the students' complaints.

Click here. Students continually discuss concepts among themselves and with the instructor during class. Discussions are spurred by multiple-choice conceptual questions that students answer using a clicker device. See supporting online text for examples of such "clicker questions."

A few years later, I discovered that the students were right. My lecturing was ineffective, despite the high evaluations. Early on in the physics curriculum—in week 2 of a typical introductory physics course—the Laws of Newton are presented. Every student in such a course can recite Newton's third law of motion, which states that the force of object A on object B in an interaction between two objects is equal in magnitude to the force of B on A—it sometimes is known as "action is reaction." One day, when the course had progressed to more complicated material, I decided to test my students' understanding of this concept not by doing traditional problems, but by asking them a set of basic conceptual questions (*1*, *2*). One of the questions, for example, requires students to compare the forces that a heavy truck and a light car exert on one another when they collide. I expected that the students would have no trouble tackling such questions, but much to my surprise, hardly a minute after the test began, one student asked, "How should I answer these questions? According to what you taught me or according to the way I usually think about these things?" To my dismay, students had great difficulty with the conceptual questions. That was when it began to dawn on me that something was amiss.

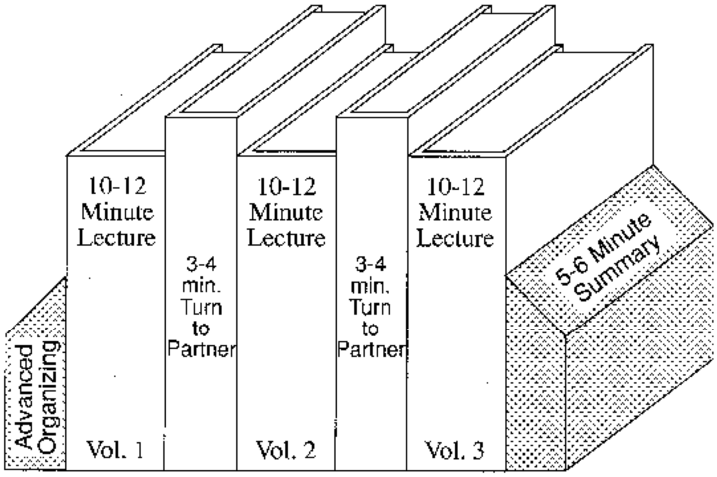
In hindsight, the reason for my students' poor performance is simple. The traditional approach to teaching reduces education to a transfer of information. Before the industrial revolution, when books were not yet mass commodities, the lecture method was the only way to transfer information from one generation to the next. However, education is so

Department of Physics, Harvard University, Cambridge, MA 02138, USA. E-mail: mazur@physics.harvard.edu

January 2, 2009—Science, Vol. 323 – www.sciencemag.org

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

Jodi Hilton for The New York Times

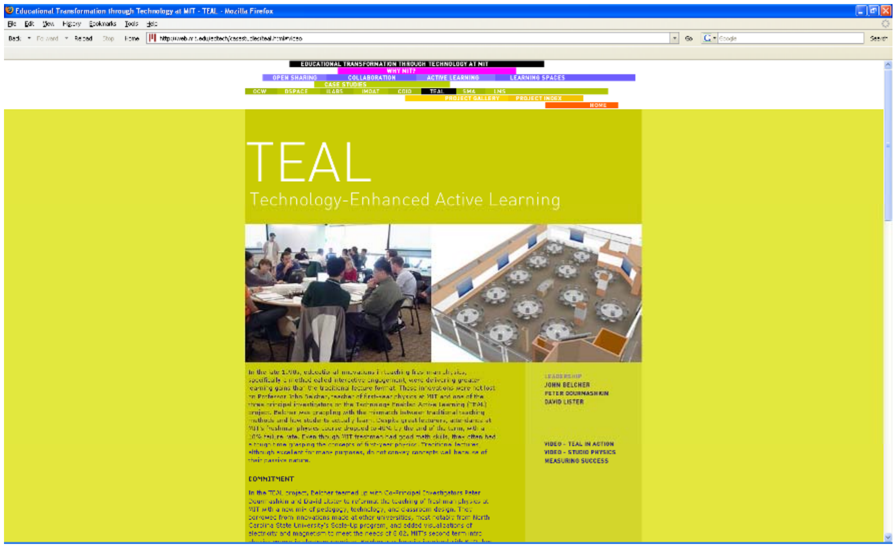
The Massachusetts Institute of Technology has changed the way it offers some introductory classes. Prof. Gabriella Sciolla at a class on electricity and magnetism.

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



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

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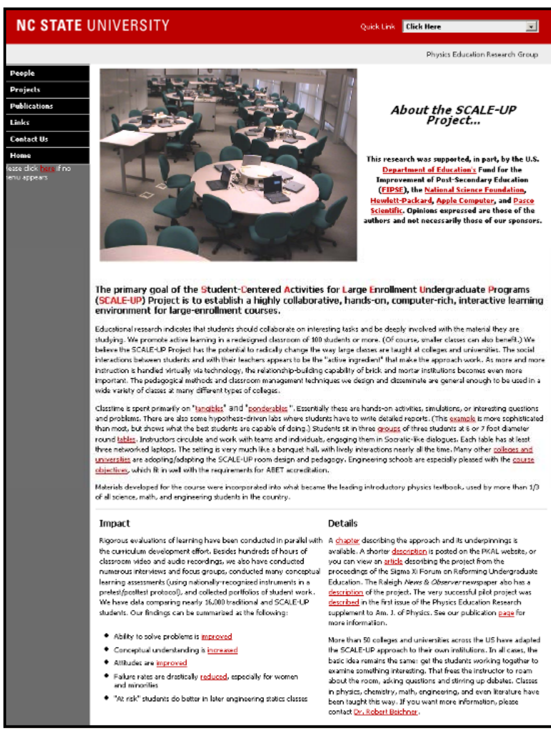

http://www.ncsu.edu/PER/scaleup.html

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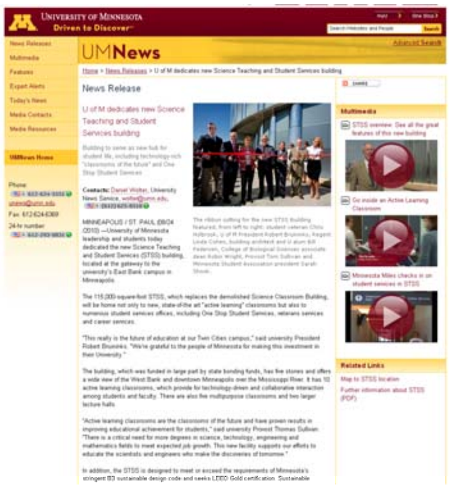

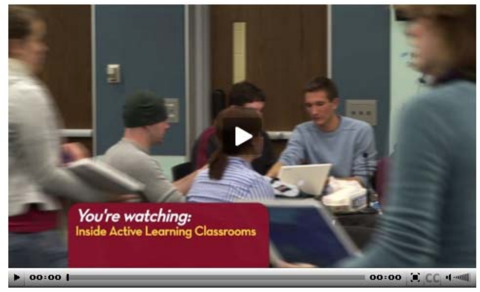

http://mediamill.cla.umn.edu/mediamill/embed/78755

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

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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.
© Univ. of Delaware, 1999.

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

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Emphasis on Innovation

- NSF TUES (CCLI) PI Meeting
  - TUES (Transforming Undergraduate Education in STEM)
  - Myles Boylan presentation
  - Carl Wieman presentation – White House – Office of Science and Technology Policy
  - http://ccliconference.org/meetings/2011-tues-conference/
- NAE FOEE
  - http://www.nae.edu/Activities/Projects20676/CASEE/26338/35816/FOEE.aspx

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The Federal Environment for STEM Education Programs: Implications for TUES

& Some of your suggestions

Myles Boylan
Division of Undergraduate Education
National Science Foundation
CCLI PI Meeting January 28, 2011

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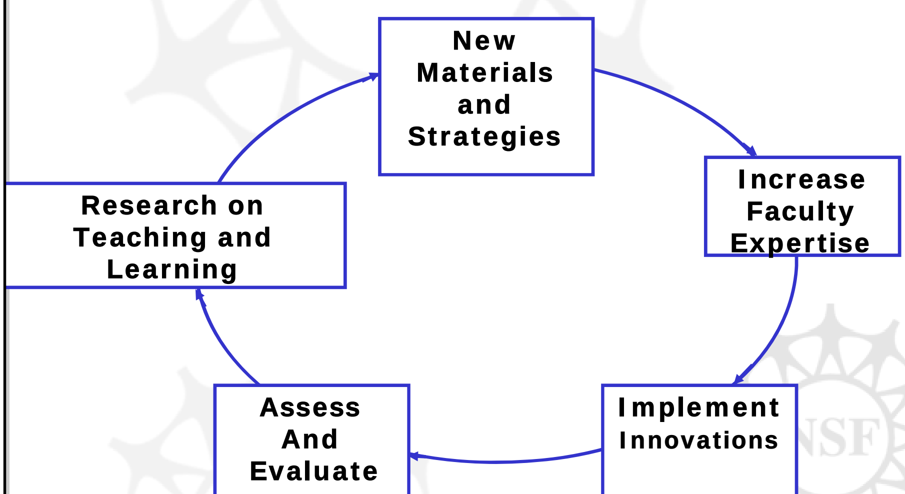
Cyclic Model for Creating Knowledge and Improving Practices in STEM Education



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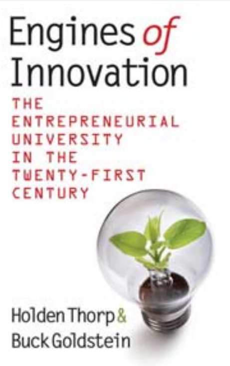
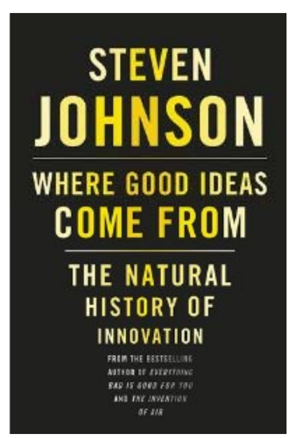
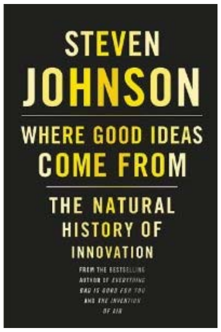
Measuring Impact in STEM Ed;
Are they thinking like experts?

Carl Wieman
Assoc. Director for Science
White House Office of Science and Technology Policy



Innovation is the adoption
of a new practice in a community





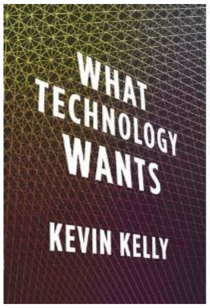
1. What is the distribution of innovations?
2. Did it change over time? If so, how?
3. Where does **your** innovation fit?

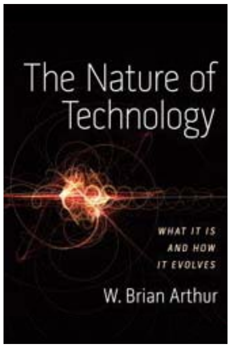
1600-1800

1800-present

1400-1600

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

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

Engineering

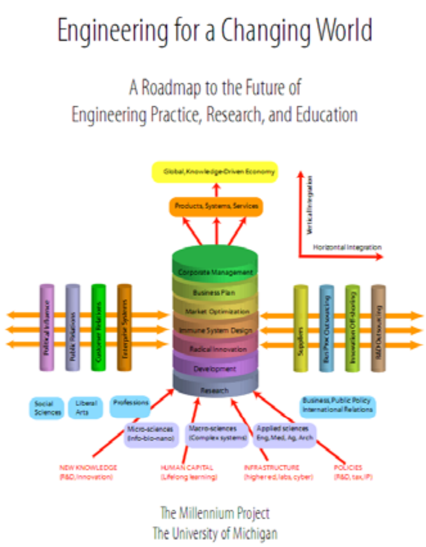
A scientist discovers that which exists. An engineer creates that which never was - Theodore von Kármán (1881-1963)

The engineering method is the use of heuristics to cause the best change in a poorly understood situation within the available resources – Billy Koen

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

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.

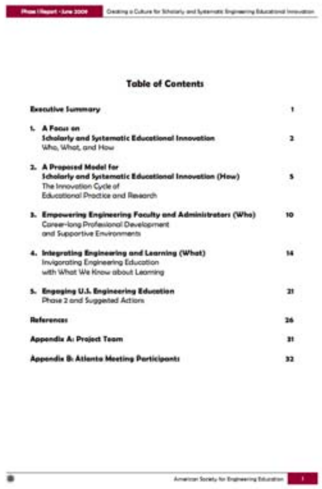
James Duderstadt, 1999 [Nuclear Engineering Professor; Dean, Provost and President of the University of Michigan]



…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



Phase I Report • June 2009 | Creating a Culture for Scholarly and Systematic Engineering Educational Innovation

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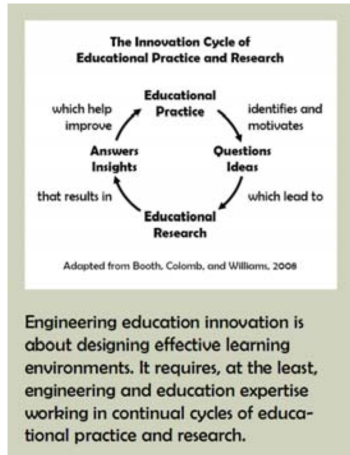
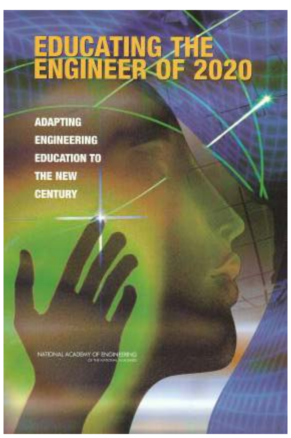


Innovation Cycle of Educational Practice and Research (Jamieson/Lohmann, 2009)

Jamieson, L.H. & Lohmann, J.L. 2009. Creating a Culture for Scholarly and Systematic Innovation in Engineering Education. ASEE. http://www.asee.org/about-us/the-organization/advisory-committees/CCSSIE

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.

Engineering Education as a Field of Research


Guest Editorial

Quiet No Longer: Birth of a New Discipline

Guest Editorial

From the Margins to the Mainstream: The Emerging Landscape of Engineering Education Research

- Engineering Education Research
  - History & Developments
  - Emerging Landscape
  - Features

Getting Started in Engineering Education Research

Fundamentals of Engineering Education Research

sponsored by the

ASEE Educational Research and Methods Division

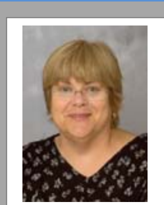
in partnership with

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

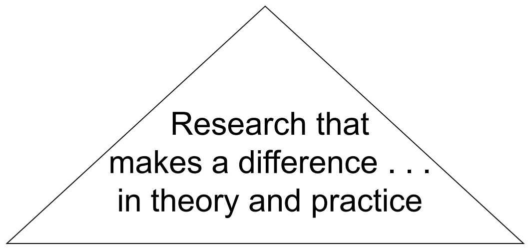
Source: Streveler, R., Borrego, M. and Smith, K.A. 2007. Moving from the "Scholarship of Teaching and Learning" to "Educational Research:" An Example from Engineering. *Improve the Academy,* Vol. 25, 139-149.

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

Theory
(study grounded in theory/conceptual framework)



Research
(appropriate design and methodology)

Practice
(implications for teaching)

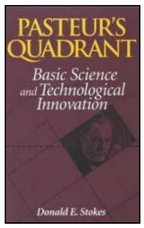
http://inside.mines.edu/research/cee/ND.htm

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

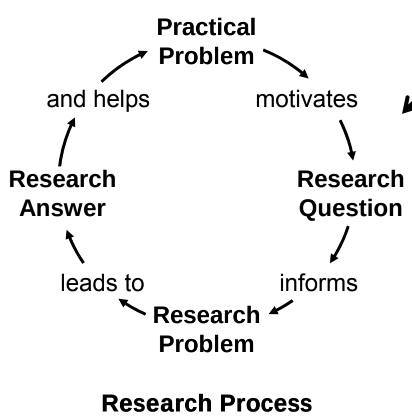
Research can be inspired by ...

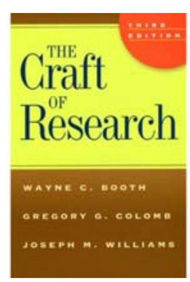


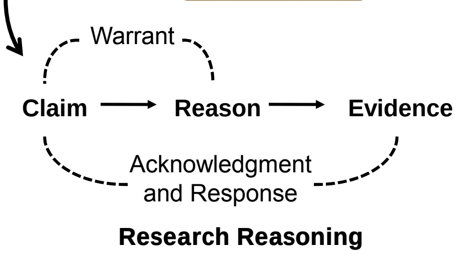
Understanding (Basic)	Use (Applied): No	Use (Applied): Yes
Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No		Pure applied research (Edison)

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

Research Process







RREE2

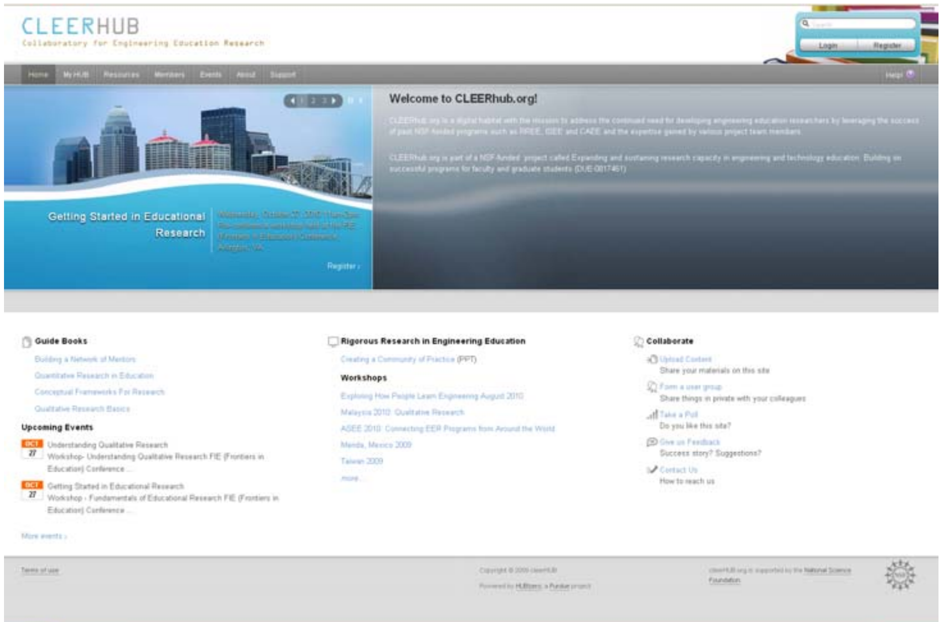
Follow-up proposal has been awarded (RREE2)

- 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**
  - **Designing Your Research Study**
    - **ASEE 2011**
- **Collaboratory for Engineering Education Research (CLEERhub.org)**



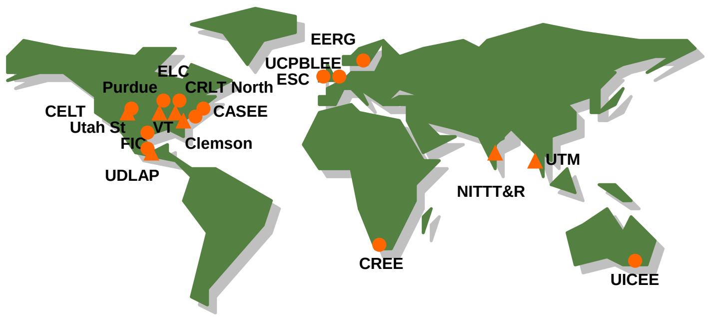
http://cleerhub.org

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.

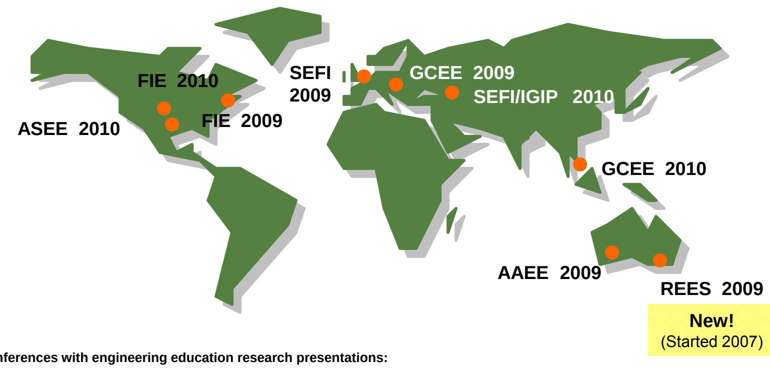
▲ **Engineering Education Degree-granting Departments** — USA: School of Engineering Education, Purdue U; Department of Engineering Education, Virginia Tech; Department of Engineering and Science Education, Clemson U; Department of Engineering and Technology Education, Utah State U; Malaysia: Engineering 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

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/

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

http://www7.nationalacademies.org/bose/DBER_Homepage.html

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- And Vanderbilt University for hosting this seminar

Thank you!

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

Vanderbilt University – CIRTL – April 12, 2011

ksmith@umn.edu