TSPE-MAG Panel: Lessons from Postsecondary Reform in Other STEM Disciplines
Two Engineering Education Reform Examples

Cooperative Learning in Engineering Education and beyond 1974 - present

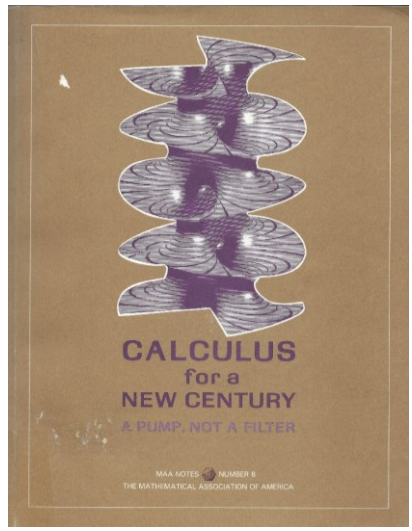
Engineering Education Research & Innovation 2004 - present

Karl A. Smith
Civil Engineering/STEM Education Center – University of Minnesota &
Engineering Education – Purdue University
ksmith@umn.edu
http://personal.cege.umn.edu/~smith/links.htm

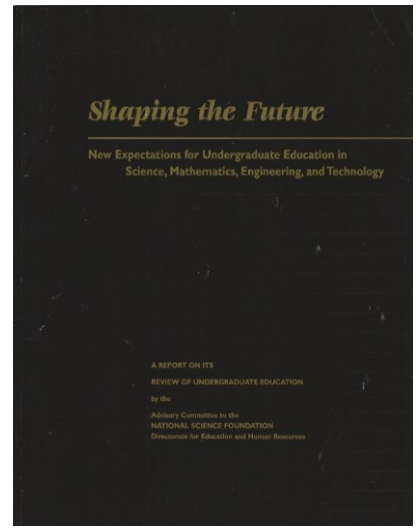
Global Calls for Reform

K-12 Engineering

Research-based Transformation



1987



1996

Lila M. Smith

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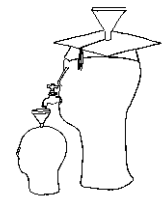
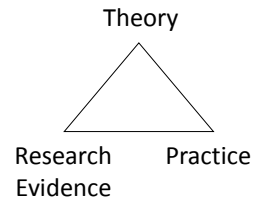
Engineering Education

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

Theory – ?

Research – ?





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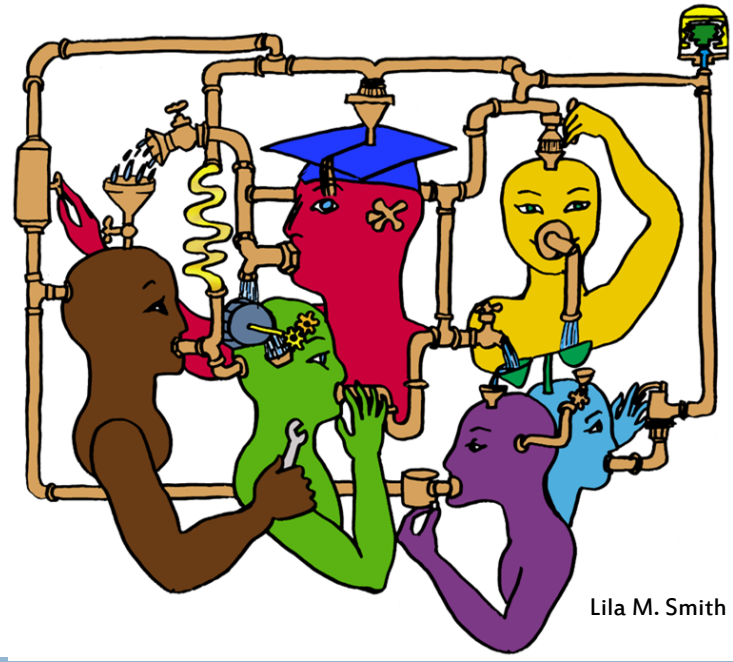

Lila M. Smith

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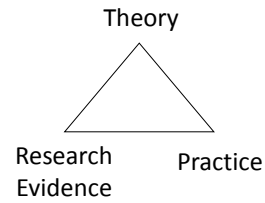
Cooperative Learning

Theory – Social Interdependence – Lewin – Deutsch – Johnson & Johnson

Research – Randomized Design Field Experiments

Practice – Formal Teams/Professor's Role



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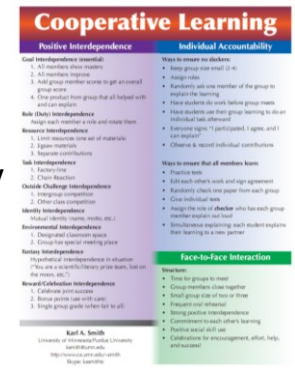
Cooperative Learning is instruction that involves people working in teams to accomplish a common goal, under conditions that involve both *positive interdependence* (all members must cooperate to complete the task) and *individual and group accountability* (each member is accountable for the complete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

Key Concepts

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



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

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Cooperative Learning Introduced to Engineering – 1981

Smith, K.A., Johnson, D.W. and Johnson, R.T., 1981. The use of cooperative learning groups in engineering education. In L.P. Grayson and J.M. Biedenbach (Eds.), *Proceedings Eleventh Annual Frontiers in Education Conference*, Rapid City, SD, Washington: IEEE/ASEE, 26-32.

Structuring Learning Goals To Meet the Goals of Engineering Education

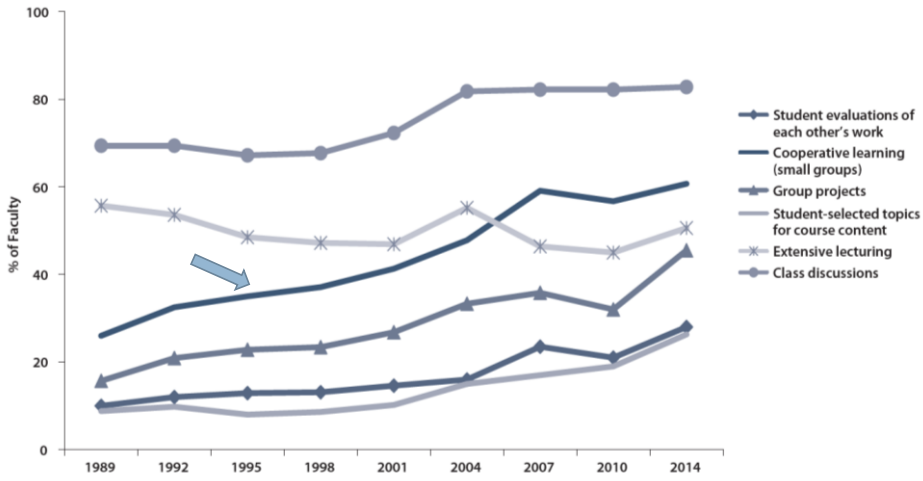
Karl A. Smith, David W. Johnson, and Roger T. Johnson
University of Minnesota

JEE December 1981

http://personal.cege.umn.edu/~smith/docs/Smith-Pedagogies_of_Engagement.pdf

Undergraduate Teaching Faculty: The 2013–2014 HERI Faculty Survey

Figure 2. Changes in Faculty Teaching Practices, 1989 to 2014
(% Marking "All" or "Most" Courses)



http://heri.ucla.edu/monographs/HERI-FAC2014-monograph.pdf

Undergraduate Teaching Faculty, 2011*

Methods Used in "All" or "Most"	STEM women	STEM men	All other women	All other men
Cooperative learning	60%	41%	72%	53%
Group projects	36%	27%	38%	29%
Grading on a curve	17%	31%	10%	16%
Student inquiry	43%	33%	54%	47%
Extensive lecturing	50%	70%	29%	44%

*Undergraduate Teaching Faculty. National Norms for the 2010-2011 HERI Faculty Survey, www.heri.ucla.edu/index.php

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

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. Journal on Excellence in College Teaching, *25*(3&4)

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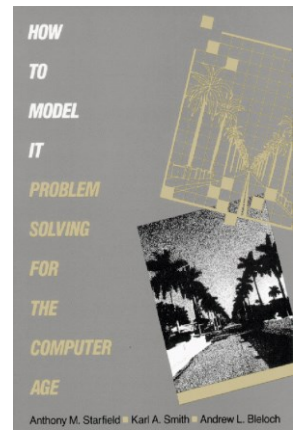
Building Models to Solve Engineering Problems
UMn and beyond ~ 1977 – present

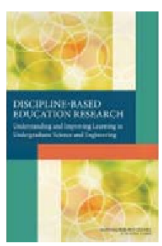
- Developing Modeling Thinking
  - Problem Identification
  - Problem Formulation
  - Problem Representation
  - Problem Solving
- Learning to Think Like an Engineer



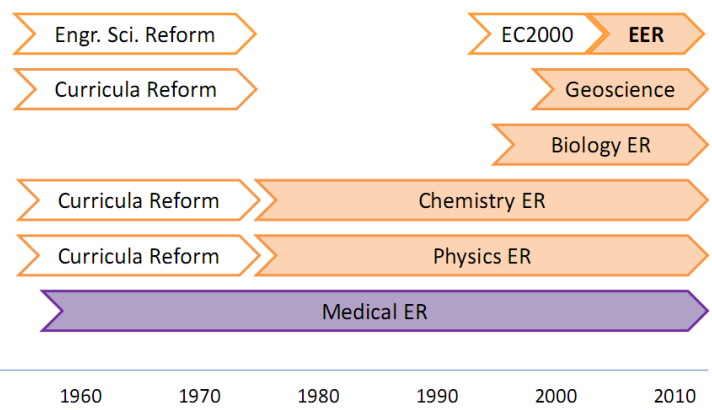
Problem-Based Cooperative Learning

Discipline-Based Education Research Timeline

DBER PhD Programs (xER)



National Research Council 2012



PURDUE ENGINEERING EDUCATION

DBER is **located** in the relevant disciplinary school, e.g. medicine, physics.

Building Engineering Education Research Capabilities:

- NSF Initiated Engineering Education Scholars Program (EESP)
- NSF – Centers for Learning and Teaching (CLT)
  - Center for the Advancement of Engineering Education (CAEE)
  - Center for the Integration of Research, Teaching, and Learning (CIRTL)
  - National Center for Engineering and Technology Education (NCETE)
- NAE: Center for the Advancement of Scholarship on Engineering Education (CASEE)
  - AREE: Annals of Research on Engineering Education
- NSF CCLI ND: Rigorous Research in Engineering Education (RREE)
- NSF CCLI Phase III project, Collaborative research: Expanding and sustaining research capacity in engineering and technology education: Building on successful programs for faculty and graduate students
- Engineering Education Research Colloquies (EERC)

Conducting Rigorous Research in Engineering Education: Creating a Community of Practice (RREE)

NSF-CCLI-ND
American Society for Engineering Education
Karl Smith & Ruth Streveler
University of Minnesota/Purdue University &
Colorado School of Mines/Purdue University

Rigorous Research in Engineering Education

- Summer Workshop - Initial Event for year-long project
- Presenters and evaluators representing
  - American Society for Engineering Education (ASEE)
  - American Educational Research Association (AERA)
  - Professional and Organizational Development Network in Higher Education (POD)
- 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)

Levels of inquiry in engineering education

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

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

RIGOROUS RESEARCH in ENGINEERING EDUCATION

Funded by the National Science Foundation through awards DUE 0341127 and DUE 0817461

Expanding and sustaining research capacity in engineering and technology education: Building on successful programs for faculty and graduate students

Collaborative partners: Purdue (lead), Alverno College, Colorado School of Mines, Howard University, Madison Area Technical College, National Academy of Engineering

A Workshop on

Building Capability and Communities in Engineering Education Research

sponsored by the

National Science Council

National Ping Tung University of Science and Technology

Meiho Institute of Technology

in partnership with

Annals of Research in Engineering Education

Journal of Engineering Education

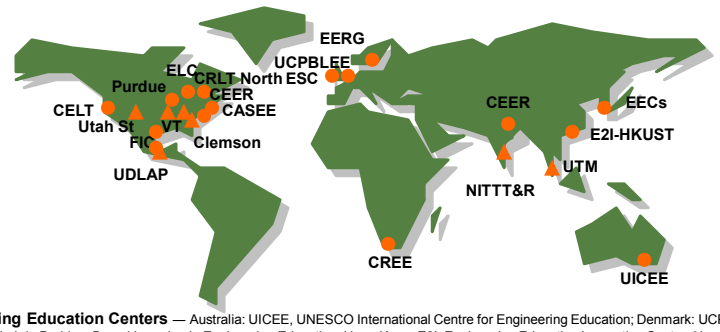
Rigorous Research in Engineering Education Initiative

Kaohsiung—Taipei, Taiwan • 2-5 February 2009

Jack R. Lohmann
Georgia Institute of Technology

Karl A. Smith
Purdue University and
University of Minnesota

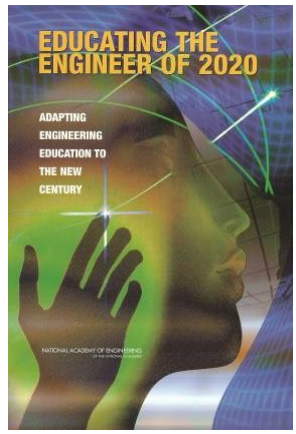
Groups, centers, departments…



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

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

Engineering Education 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.