

# 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

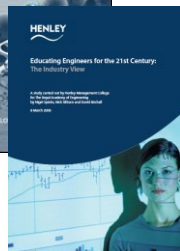
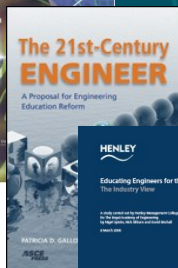
**Karl A. Smith**

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University of Minnesota &  
Engineering Education – Purdue University  
[ksmith@umn.edu](mailto:ksmith@umn.edu)  
<http://personal.cege.umn.edu/~smith/links.htm>

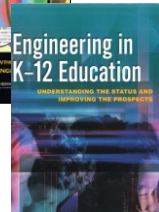
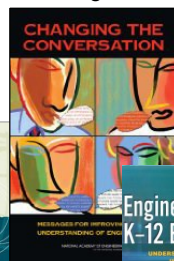
Transforming Post-Secondary Education – Mathematics Advisory Group

March 25, 2016

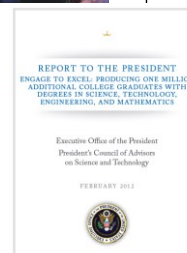
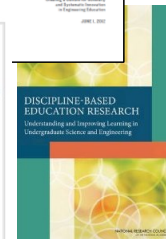
### Global Calls for Reform

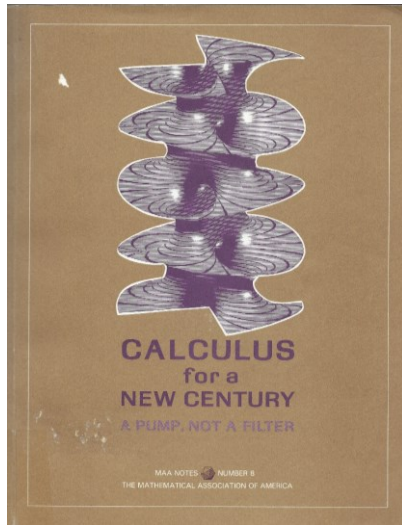


### K-12 Engineering

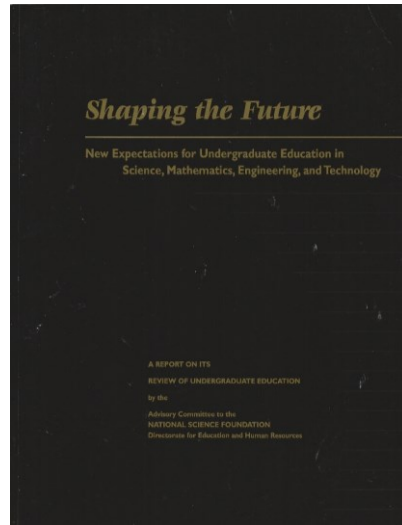


### Research-based Transformation





1987



1996



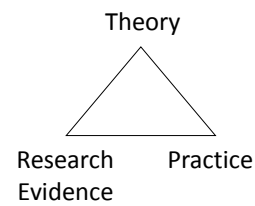
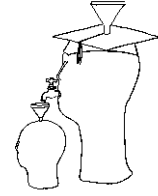
Lila M. Smith

# Engineering Education

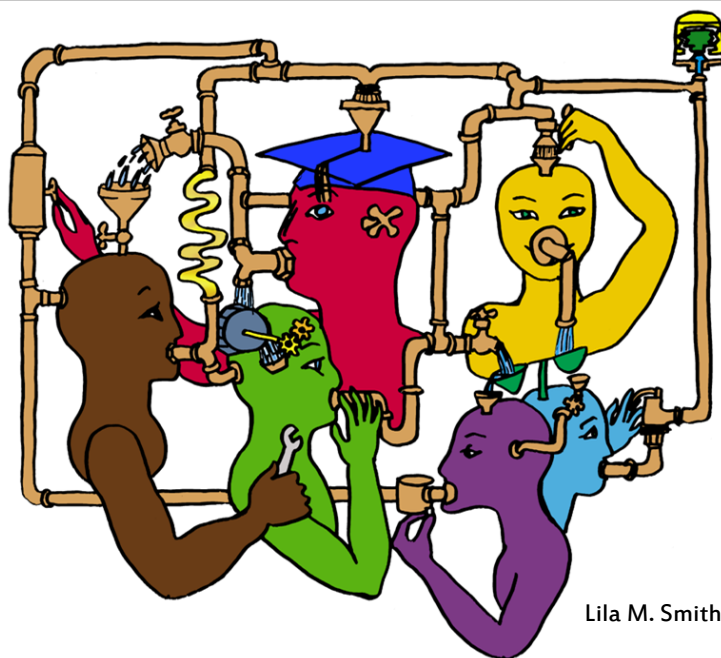
Practice – Third-year course in metallurgical reactions – thermodynamics and kinetics

Theory – ?

Research – ?



5



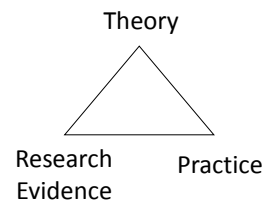
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# Cooperative Learning

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

Cooperative Learning	
Positive Interdependence	Individual Accountability
<p><b>Goal Interdependence</b> essential:</p> <ol style="list-style-type: none"> <li>1. All members share responsibility</li> <li>2. All members have a role to play</li> <li>3. All group members must work together to achieve the goal</li> <li>4. One member's success is dependent on the success of the group</li> </ol> <p><b>Role Interdependence</b></p> <p>Assign each member a role and make them responsible for it.</p> <ol style="list-style-type: none"> <li>1. Limit resources (time, money, etc.)</li> <li>2. Assign resources</li> <li>3. Assign responsibilities</li> </ol> <p><b>Task Interdependence</b></p> <ol style="list-style-type: none"> <li>1. Randomize</li> <li>2. Assign tasks</li> <li>3. Assign responsibilities</li> </ol> <p><b>Outside Challenge Interdependence</b></p> <ol style="list-style-type: none"> <li>1. Assigning competition</li> <li>2. Other class competition</li> </ol> <p><b>Ability Interdependence</b></p> <p>Mix ability (strong, middle, etc.)</p> <p><b>Individual Accountability</b></p> <ol style="list-style-type: none"> <li>1. Designated classroom space</li> <li>2. Group for general learning goals</li> </ol> <p><b>Teamwork Interdependence</b></p> <p>Establish interdependence in classroom</p> <p>"You are a member of the team, not just a member of the class."</p> <p><b>Reward/Consequence Interdependence</b></p> <ol style="list-style-type: none"> <li>1. Assigning competition</li> <li>2. Reward points (use with care)</li> <li>3. Group group points (use with care)</li> </ol>	<p><b>Steps to ensure no shirkers</b></p> <ul style="list-style-type: none"> <li>• Keep group size small (3-4)</li> <li>• Assign roles</li> <li>• Randomly select one member of the group to report the progress</li> <li>• Have students do work before group meets</li> <li>• Have students use their group learning to do an individual task afterward</li> <li>• Randomly assign 1-2 participants (1 agree, 1 can explain)</li> <li>• Observe &amp; record individual contributions</li> </ul> <p><b>Steps to ensure that all members learn</b></p> <ul style="list-style-type: none"> <li>• Practice role</li> <li>• Ask each other's work and sign agreement</li> <li>• Randomly check one paper from each group</li> <li>• Give individual task</li> <li>• Assign the role of teacher who has each group member explain to the class</li> <li>• Encourage explaining each student explains their learning to a new partner</li> </ul> <p><b>Face-to-Face Interaction</b></p> <p><b>Structure</b></p> <ul style="list-style-type: none"> <li>• Time for groups to meet</li> <li>• Group members share together</li> <li>• Small group size of four or five</li> <li>• Random and alternate</li> <li>• Strong positive interdependence</li> <li>• Commitment to each other's learning</li> <li>• Positive social skill use</li> <li>• Collaborative for encouragement, effort, help, and success</li> </ul>

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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

The growing concern about engineering education in the United States has led to a re-examination of the goals of engineering education and a search for ways to meet these goals. This paper presents the authors' perspective on the goals of engineering education and the ways to meet these goals. The authors argue that the goals of engineering education are to prepare students to solve problems, to work in teams, and to communicate effectively. They argue that these goals can be met by using cooperative learning groups in the classroom.

**Goals of Engineering Education**  
The three major goals of engineering education are to prepare students to solve problems, to work in teams, and to communicate effectively. These goals are the foundation of engineering education and are the basis for all other goals. The authors argue that these goals can be met by using cooperative learning groups in the classroom.

the interaction between society and technology.

### Needs of Engineering Graduates

Many studies have been conducted on the needs of engineering graduates. These studies have found that graduates need to be able to solve problems, to work in teams, and to communicate effectively. These are the same goals that the authors argue for in their paper.

1. There is a general consensus that, despite many efforts, engineering education is not yet meeting what is called the "humanistic goals" of engineering education.

2. Engineering education must be more student-oriented, that is, more concerned with the needs of the students.

3. Engineers must be made more aware of the importance of engineering in American life, and must be given a corresponding important part in the decision-making process.

The recommendations of these studies are similar to the authors' goals. The authors argue that these goals can be met by using cooperative learning groups in the classroom.

The results of the major studies of engineering education lead to the conclusion that the need for engineering education is to prepare students to solve problems, to work in teams, and to communicate effectively. These are the same goals that the authors argue for in their paper.

JEE December 1981

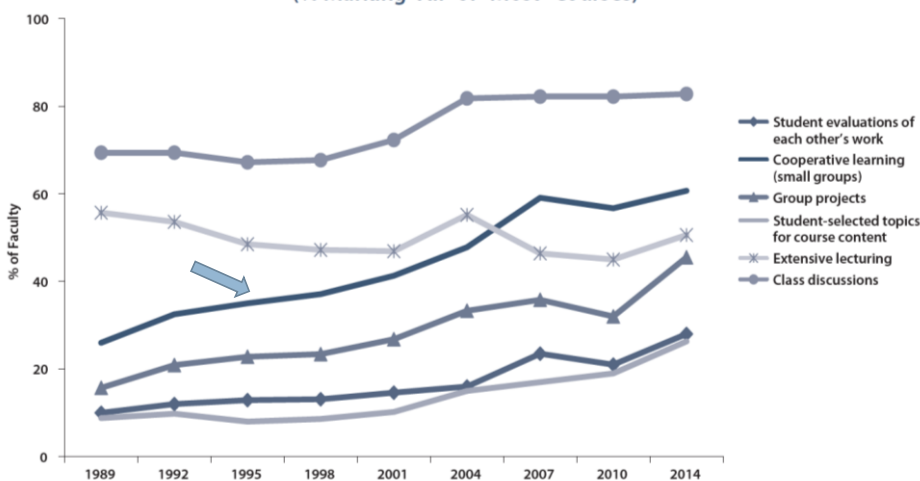
PROCEEDINGS EDUCATION 1981 / 321

[http://personal.cege.umn.edu/~smith/docs/Smith-Pedagogies\\_of\\_Engagement.pdf](http://personal.cege.umn.edu/~smith/docs/Smith-Pedagogies_of_Engagement.pdf)

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## 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>

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## 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](http://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

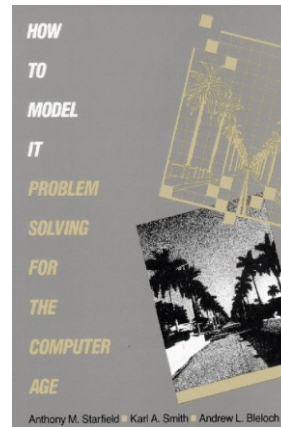


March 2007

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)

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

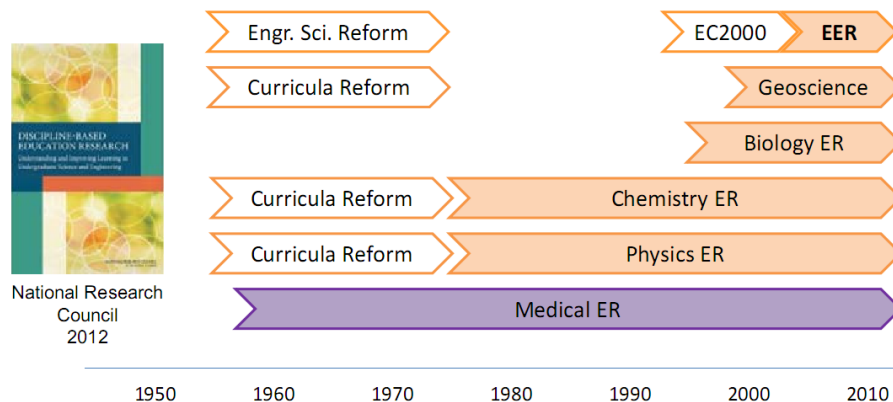
- Developing Modeling Thinking
  - Problem Identification
  - Problem Formulation
  - Problem Representation
  - Problem Solving
- Learning to Think Like an Engineer



Problem-Based Cooperative Learning

## Discipline-Based Education Research Timeline

DBER PhD Programs (xER)



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**

*The Community of Practice*





## 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

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*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

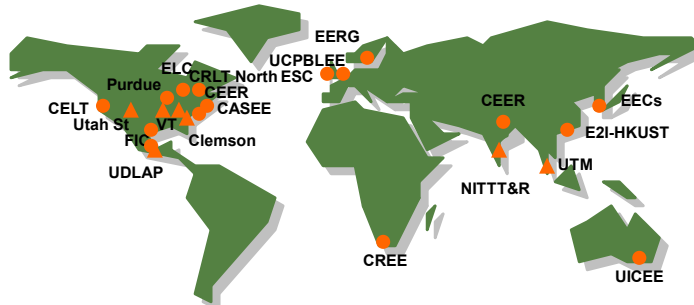


**Jack R. Lohmann**  
Georgia Institute of Technology



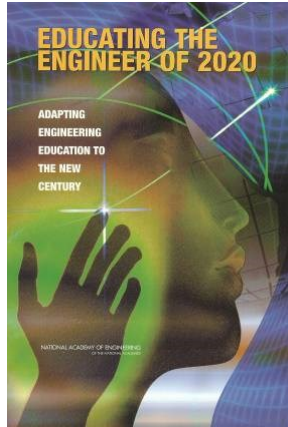
**Karl A. Smith**  
Purdue University and  
University of Minnesota

## 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.*