Implementing evidence-based instructional practices in engineering education

Society of Engineering Education Malaysia

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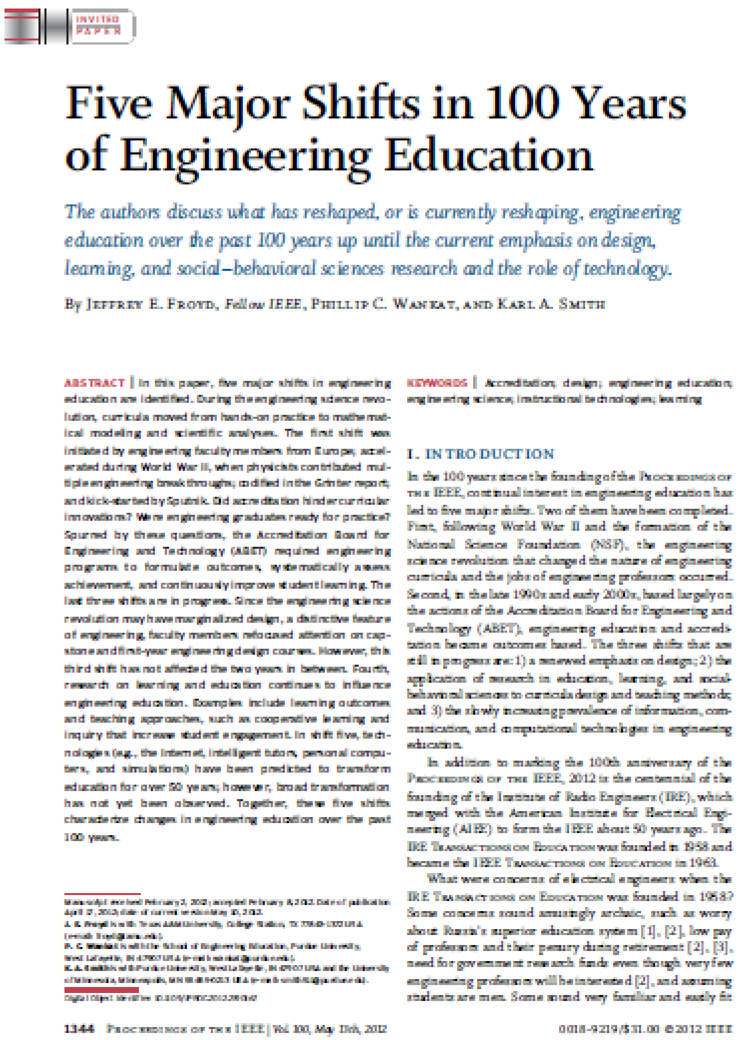
Overview

1. Change is hard and it does happen
2. Why doesn't knowing lead to doing?
3. Examples of change initiatives
    1. Cooperative Learning
    2. Discipline-Based Education Research (DBER) - RREE project
    3. Remote Learning
4. Change studies/resources
    1. Kezar – Communities of Transformation
    2. Accelerating Systemic Change in STEM Undergraduate Education (ASCN)



Five Major Shifts in 100 Years of Engineering Education

The authors discuss what has reshaped, or is currently reshaping, engineering education over the past 100 years up until the current emphasis on design, learning, and social–behavioral sciences research and the role of technology.

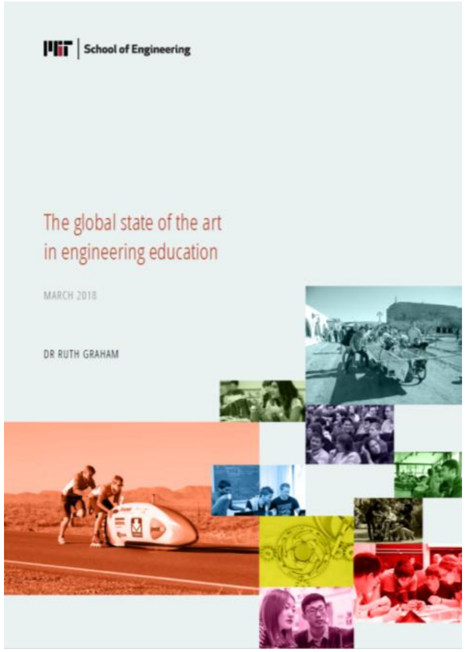
By Jeffrey E. Froyd, Fellow IEEE, Phillip C. Wankat, and Karl A. Smith

1. a shift from hands-on and practical emphasis to engineering science and analytical emphasis;
2. a shift to outcomes-based education and accreditation;
3. a shift to emphasizing engineering design;
4. **a shift to applying education, learning, and social-behavioral sciences research**;
5. a shift to integrating information, computational, and communications technology in education.

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&tp=&arnumber=6185632

Previous Shifts

- Were prompted by outside forces
- Were met with resistance
- Were eventually embraced (to varying degrees)
- They did not change core values/practices



- What is the future direction for the engineering education sector?
  - The **first anticipated trend** is a tilting of the global axis of engineering education leadership.
  - The **second anticipated trend** is a move towards socially-relevant and outward-facing engineering curricula.
  - The **third anticipated trend** for the sector is therefore the emergence of a new generation of leaders in engineering education that delivers integrated student-centered curricula at scale.

"This is the future of the field, where you put the student at the center and use the resources to facilitate team projects and authentic experiences, and then put the taught curriculum online."

https://jwel.mit.edu/sites/mit-jwel/files/assets/files/neet_global_state_of_eng_edu_180330.pdf

Cooperative Learning: An Evidence-Based Practice for Interactive Learning

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).

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 been the subject of many recent editorials and articles.* They point to the deteriorating quality of engineering and science education, the lack of adequate preparation in mathematics and science on the part of high school graduates, the shortage of engineers, and, especially, the shortage of college teachers of engineering. Unless corrective measures are taken, it may be more difficult in the coming years to achieve the goals of engineering education and to meet the needs of engineering students.

Goals of Engineering Education

The three major goals of engineering education are to promote technological, interpersonal, and social-technical competencies in engineering students. The achievement of *technological competence* requires the mastery and retention of science and engineering facts, principles, theories and analytical skills; the development of synthesis, design, modeling and problem solving skills; and the development of implementation skills for converting knowledge into action.

Interpersonal competence requires the development of the cognitive, affective and behavioral prerequisites for working with others to perform a task.[1] Among the skills required are communication, constructive conflict management, interpersonal problem solving, joint decision making and perspective-taking skills. Interpersonal competence is becoming increasingly important for engineers due to the tremendous technical complexity and the societal constraints of most problems. Engineers must now, more than ever, work with other engineers and scientists, economists, educators, consumer groups, and government regulatory agencies to reach satisfactory and mutually acceptable designs for future technology.

Social-technical competence requires gaining an understanding of the complex interdependencies between technology and society, of the influence of technology on individual and collective behavior and on the natural environment. Essentially, social-technical competence involves perspective-taking on a large scale that encompasses historical, social, psychological, and philosophical viewpoints, as well as an understanding of the basic premises underlying the interaction between society and technology.

Needs of Engineering Graduates

Many studies have been conducted on engineering education since it began at West Point in 1792, and these have been well summarized.[2] The earliest study (by Mann in 1918) called for a return to the basics; each of the subsequent ones emphasized diversity and a broad education,[3] and their general findings have been summarized by Cheit[4] in the following three statements:

1) There is renewed concern that, despite many efforts, engineering education is not yet incorporating what is called the "humanistic-social," "liberal," or "general" parts of the students' education.

2) Engineering education must be more broadly applied, that is, engineers must build bridges between science and the needs of society.

3) Engineers must be made decision makers, since, despite the growing importance of engineering to American life, engineers have not taken a correspondingly important part in the decision-making process.

The recommendations of these studies are similar and recurrent, but the need for change in engineering education remains. Currently, there appears to be a move away from the image of applied science in engineering education.[5] The basis of this apparent change is the growing realization that technological and economic feasibility are not the sole or even the main determinants of what engineers do. Ecological, social, cultural, psychological and political influences are equally important.

The results of the major studies of engineering education tie in closely with the need for developing social-technical competence and interpersonal competence in engineering graduates. Supporting this need, a major study at the University of California, Los Angeles, concluded that every engineering graduate must be capable of communicating with and working with people of other professions to solve the inter-

*See, for example, recent issues of *Engineering Education* (e.g., April 1981) and *Science* (e.g., "Trouble in Science & Engineering Education," by J. Walsh, vol. 200, no. 4470, 1980.)

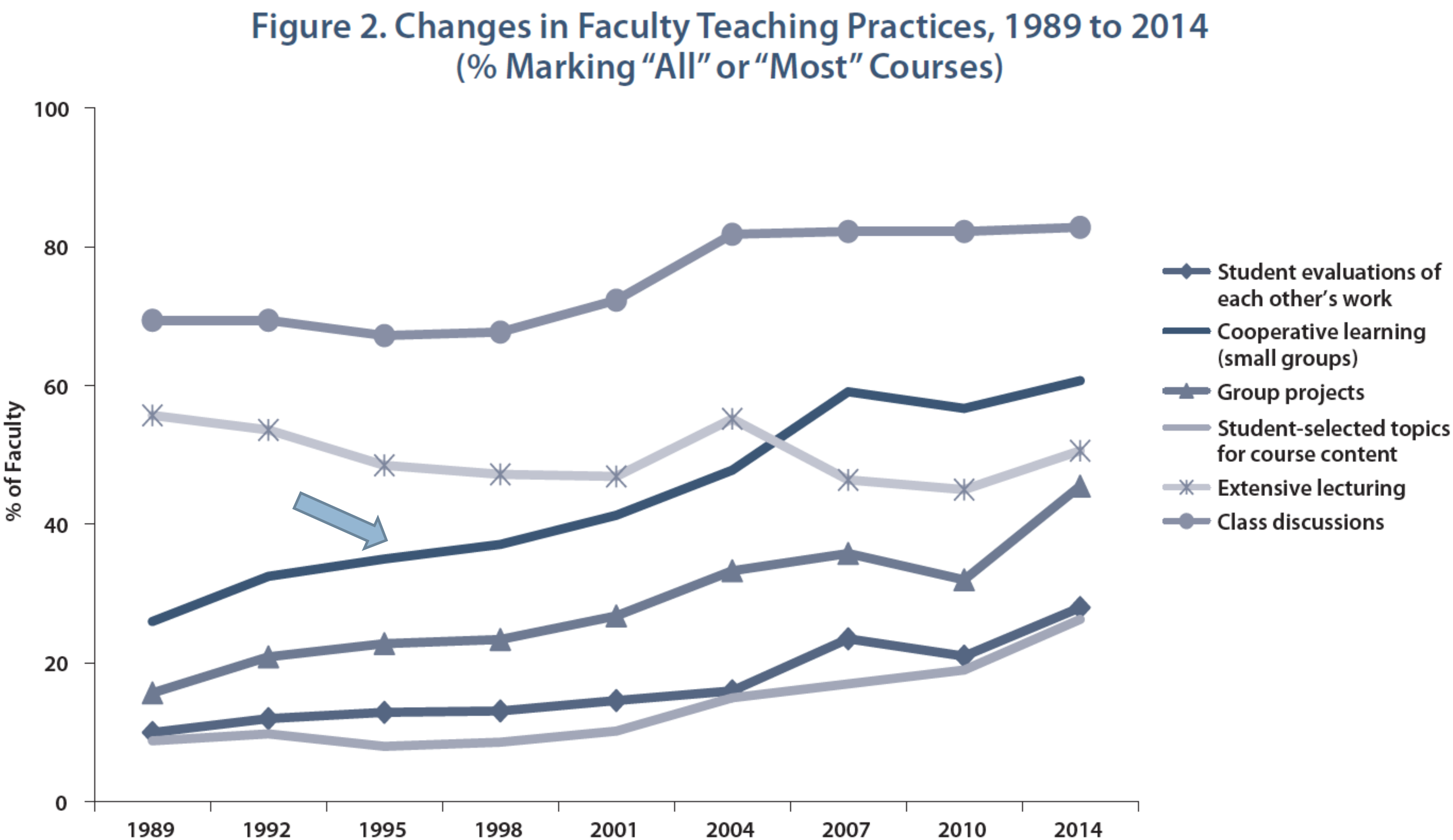
https://karlsmithmn.org/wp-content/uploads/2017/08/Smith-Johnson-Johnson-Structuring_Learning-JEE-1981.pdf

What Matters in College

- Environmental factors most predictive of positive change in students' academic development, personal development, and satisfaction:
  - **Interaction among students and**
  - **Interaction between faculty and students**

Astin (1985) *What Matters in College: Four Critical Years Revisited. Jossey-Bass*

Undergraduate Teaching Faculty: The 2013–2014 HERI Faculty Survey



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: Lessons and Insights from Thirty Years of Championing a Research-Based Innovative Practice

Karl A. Smith
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***Abstract* - Innovation according to Denning and Dunham (2010) is "the adoption of a new practice in a community." I argue that our innovations need to be based on good learning theory and good instructional practice. The Johnson and Johnson conceptual model of cooperative learning is an excellent example of a widely adopted evidence-based practice. I identified cooperative learning as important for engineering education in about 1974, tried it in my classes and did some systematic research on it with David and Roger Johnson, introduced it to the engineering education community in 1981 (FIE conference and JEE paper), and it took over 25 years for it to become widespread practice. My point in presenting this story is I don't think we can afford to wait 25 or more years for the current innovations to make it into practice. This paper summarizes the history of the emergence of cooperative learning in engineering education; documents the development of the theoretical, empirical, and practical support; maps the milestones and lessons learned; and provides insights and guidance for engineering education researchers and innovators especially concerning increasing the rate of adoption of evidence-based promising practices.**

Index Terms – cooperative learning, evidence-based promising practice, engineering education research and innovation

Clarification

Since there is the possibility of a confusion of terms, I'm starting with the definition of cooperative learning and highlighting how it is different from collaborative learning and cooperative education (or co-op). [Note: Thanks to the anonymous reviewer who recommended this addition]

Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each others' learning (Johnson and Johnson, 1974; Smith, Johnson and Johnson, 1981; Johnson, Johnson and Smith, 1991). Carefully structured cooperative learning 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 individually as well as all members collectively accountable for the work of the group).

A common question is, "What is the difference between cooperative and collaborative learning?" Both pedagogies are aimed at "marshalling peer group influence to focus on intellectual and substantive concerns" (Matthews, et.al, 1995). The principal difference is that cooperative learning requires carefully structured individual accountability, whereas collaborative learning does not. Oxford (1997) summarizes the differences as follows, "Cooperative learning refers to a particular set of classroom techniques that foster learner interdependence as a route to cognitive and social development. Collaborative learning has a "social constructivist" philosophical base, which views learning as construction of knowledge within a social context and which therefore encourages acculturation of individuals into a learning community."

Another potential source of confusion is cooperative education (or co-op), which is "is a structured method of combining classroom-based education with practical work experience. A cooperative education experience, commonly known as a "co-op", provides academic credit for structured job experience" (Auld, 1972).

History

[Note: History and Concurrent Developments sections were adapted from Smith (2010)]
My first encounter with cooperative learning occurred in about 1974 in a Social Psychology of Education course taught by one of David Johnson's PhD students, Dennis Falk who is currently a Professor of Social Work at the University of Minnesota – Duluth. I began taking courses in the College of Education in the early 70s because I had an overwhelming sense that there was a better way to help engineering students learn than what I was doing, which was essentially what had been done to me, that is, lecture, homework assignments and individual exams. This overwhelming sense of a better way of doing things was prompted by questions the students asked, which revealed that they had no idea what I was talking about. A representative setting was a course in thermodynamics and kinetics – very abstract areas involving a lot of mathematics – where I was "teaching as taught." My sense that there was a better way was grounded in my training and experience as an engineer, where one of the fundamental ideas is "advancing the state-of-the-art". What I encountered in the

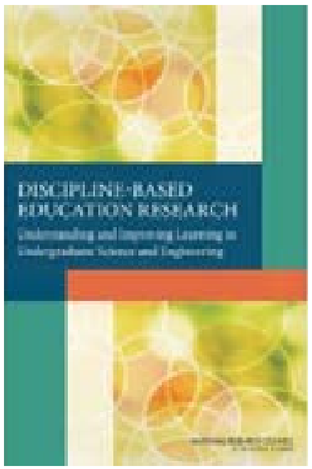
https://karlsmithmn.org/wp-content/uploads/2017/08/Smith-FIE-CL-1240-10-draft.pdf

Effectiveness of Interactive Learning

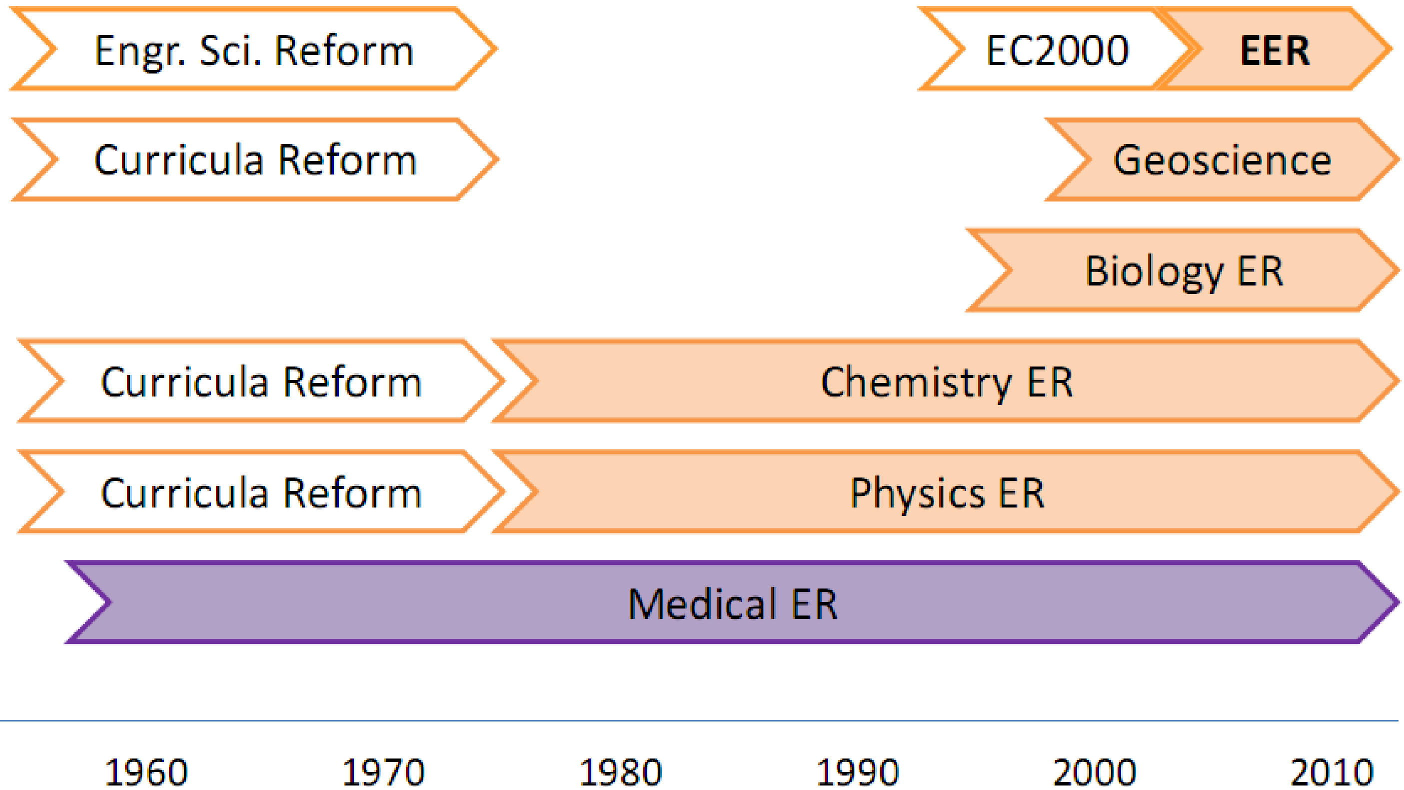
- Johnson, D. W., R. T. Johnson, and K. A. Smith. 2014. Cooperative Learning: Improving University Instruction by Basing Practice on Validated Theory. In Small-group Learning in Higher Education: Cooperative, Collaborative, Problem-based, and Team-based Learning, *Journal on Excellence in College Teaching 35*, nos.3 and 4.
- Meta-analyses in the *Proceedings of the National Academy of Sciences (PNAS)* summarize the importance of interactive learning for
  - reducing the failure rate (Freeman, et.al. 2014) https://www.pnas.org/content/111/23/8410
  - narrowing the achievement gap for underrepresented students (Theobald, et.al. 2019) https://www.pnas.org/content/117/12/6476

Discipline-Based Education Research Timeline

DBER Departments and Graduate Programs



National Research Council
2012



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

Fundamentals of Engineering Education Research

Rigorous Research in Engineering Education Initiative
(NSF DUE 0817461)
https://stemedhub.org/groups/cleerhub

Ruth A.Streveler
Purdue University

Karl A. Smith
Purdue University and
University of Minnesota

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

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.

Workshop Intentions / Participant Learning Outcomes

1. Describe key features of engineering education research
2. Explain emergence of engineering education research as a discipline
3. Describe recent reports and their relevance for and relationship with engineering education research
4. Summarize growth of engineering education research
5. Speculate on the future of engineering education research

RREE Approach

Theory

(study grounded in theory/conceptual framework)

Research that
makes a difference . . .
in theory and practice

Research Evidence

(appropriate design and methodology)

Practice

(implications for teaching)

RREE

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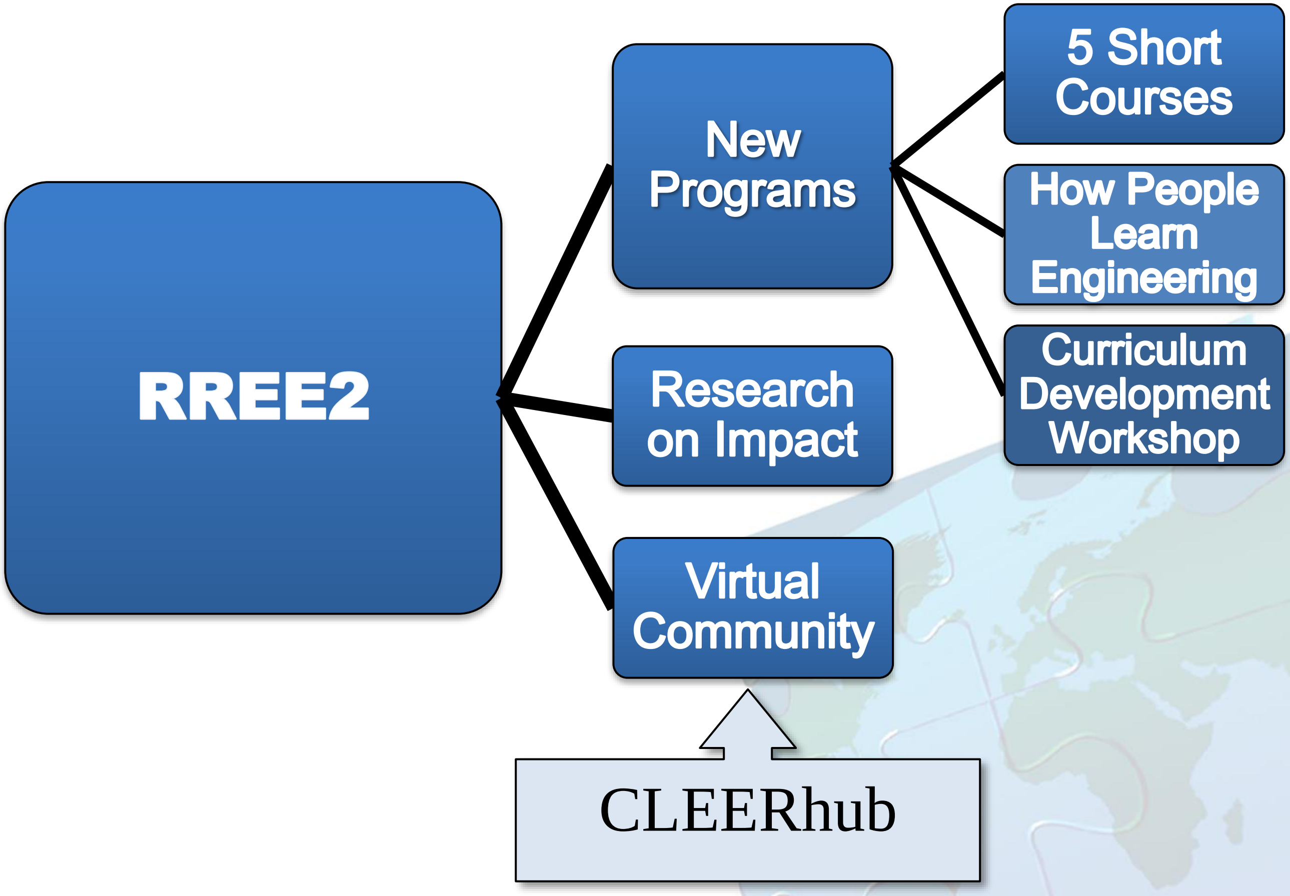
Collaborative partners: Purdue (lead), Alverno College, Colorado School of Mines, Howard University, Madison Area Technical College, National Academy of Engineering



https://stemedhub.org/groups/cleerhub

RIGOROUS RESEARCH in ENGINEERING EDUCATION

RREE2

Follow-up proposal (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

*Recorded and posted on https://stemedhub.org/groups/cleerhub

Centrality of Community of Practice (CoP)

- Streveler, R.A., Smith, K.A., and Miller, R.L. 2005. Enhancing Engineering Education Research Capacity through Building a Community of Practice.
- Streveler, R.A., Magana, A.J., Smith, K.A. and Douglas, T.C. 2010. CLEERHub.org: Creating a digital habitat for engineering education researchers. American Society for Engineering Education Annual Conference
- Pitterson, N., Allendoerfer, C., Streveler, R., Ortega-Alvarez, J., & Smith, K. (2020). The Importance of Community in Fostering Change: A Qualitative Case Study of the Rigorous Research in Engineering Education (RREE) Program. *Studies in Engineering Education*, *1*(1), 20–37. DOI: http://doi.org/10.21061/see.7 https://www.seejournal.org/articles/10.21061/see.7/

EER&I Networking Session

Connecting and Expanding the Engineering Education Research & Innovation (EER&I) Communities

ASEE Annual Conference – June 18, 2019– T474 – 1:30 pm – 3:00 pm

Facilitated By

Karl A. Smith
Purdue University and University of Minnesota

Ruth A. Streveler
Purdue University

Rocio Chavela Guerra
American Society for Engineering Education

UNIVERSITI TEKNOLOGI MALAYSIA CENTRE FOR ENGINEERING EDUCATION: LOCAL & GLOBAL ACTIVITIES

Scholarly Innovations, Research & PhD in Engineering Education

More than 20 PhD graduates since 2011
Current students: 16

Translating research into practice

JICA-funded PBL for Low Carbon Society with Kyoto Environ. Activities Assoc. & Johor State Edu. Dept

Research & knowledge implementation & dissemination

Training, Mentoring, & Recognition

4 international & 8 national awards

Active Learning

Team Based Learning

Cooperative Problem Based Learning (CPBL)

Training: Effective SCL implementation for Engaging Millennials

Community of practice – enable and support

Champions & Communities of change agents

International Innovative Practices in Higher Education Expo (I-PHEX)

International Engineering Service Learning with Korea &

Champions and trainers (TOT) – World Bank-funded project with MOHE Afghanistan

Contact: khairiyah@utm.my

PURDUE UNIVERSITY | School of Engineering Education
COLLEGE OF ENGINEERING

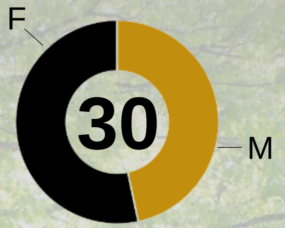
Celebrating 15 YEARS
PURDUE UNIVERSITY School of Engineering Education COLLEGE OF ENGINEERING
ESTABLISHED APRIL 9, 2004

UNDERGRADUATE ENROLLMENT AY 2018-19

First-Year Engineering **~2800**

Multidisciplinary Engineering **88**

FACULTY GENDER RATIO

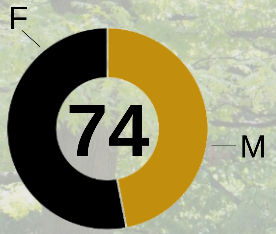


30 Faculty
26 AP Staff
7 Admin Assistants

CURRENT PHD STUDENTS

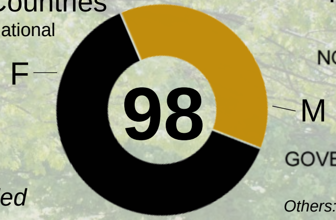
Representing 14 Countries

2 or more
Brazil
Canada
China
Colombia
India
Iran
Pakistan
United States



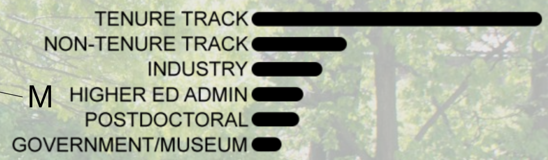
PHD ALUMNI*

Representing 15 Countries
and 54 Domestic and International Universities and Colleges



*Successfully Defended

PHD ALUMNI CAREERS



Others: P-12 Education, Higher Ed Research, Unknown

PROGRAMS and OPERATIONS

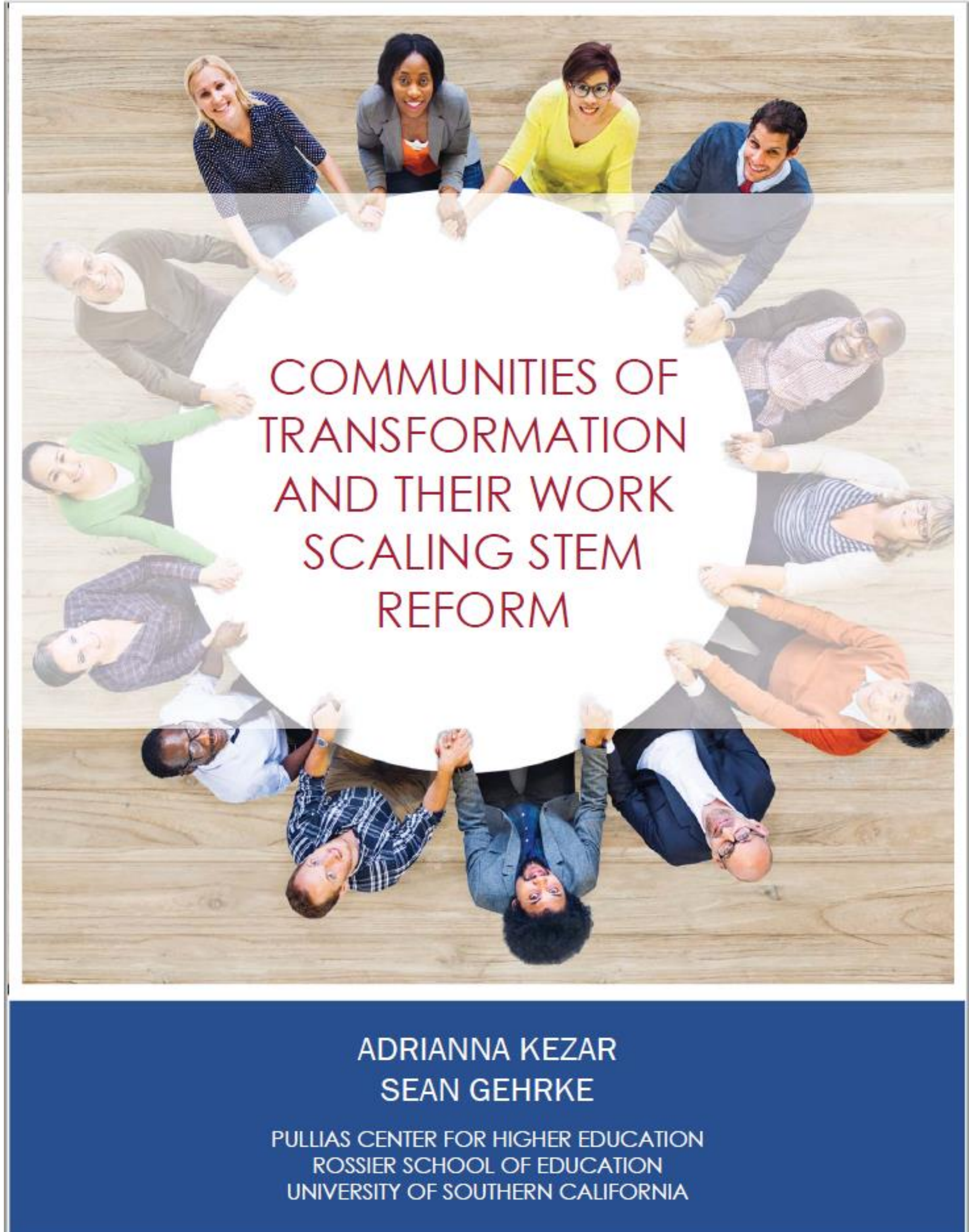
First-Year Engineering Program
Graduate Program (MS and PhD)
Multidisciplinary Engineering Degree Program
INSPIRE Pre-College Engineering Research
Student Advising
Graduate Certificate (New 2016; Online New 2018)
Integrated Research Labs
Ideas To Innovation Learning Labs

CAMPUS COLLABORATIONS

Biomedical Engineering
Chemical Engineering
Electrical and Computer Engineering
Environmental and Ecological Engineering
Materials Engineering
Mechanical Engineering

Honors College
Purdue Polytechnic Institute
Krannert School of Management
College of Education
College of Health and Human Services
College of Liberal Arts
Purdue Athletics

INTEGRATING RESEARCH AND PRACTICE



https://pullias.usc.edu/download/communities-of-transformation-and-their-work-scaling-stem-reform/

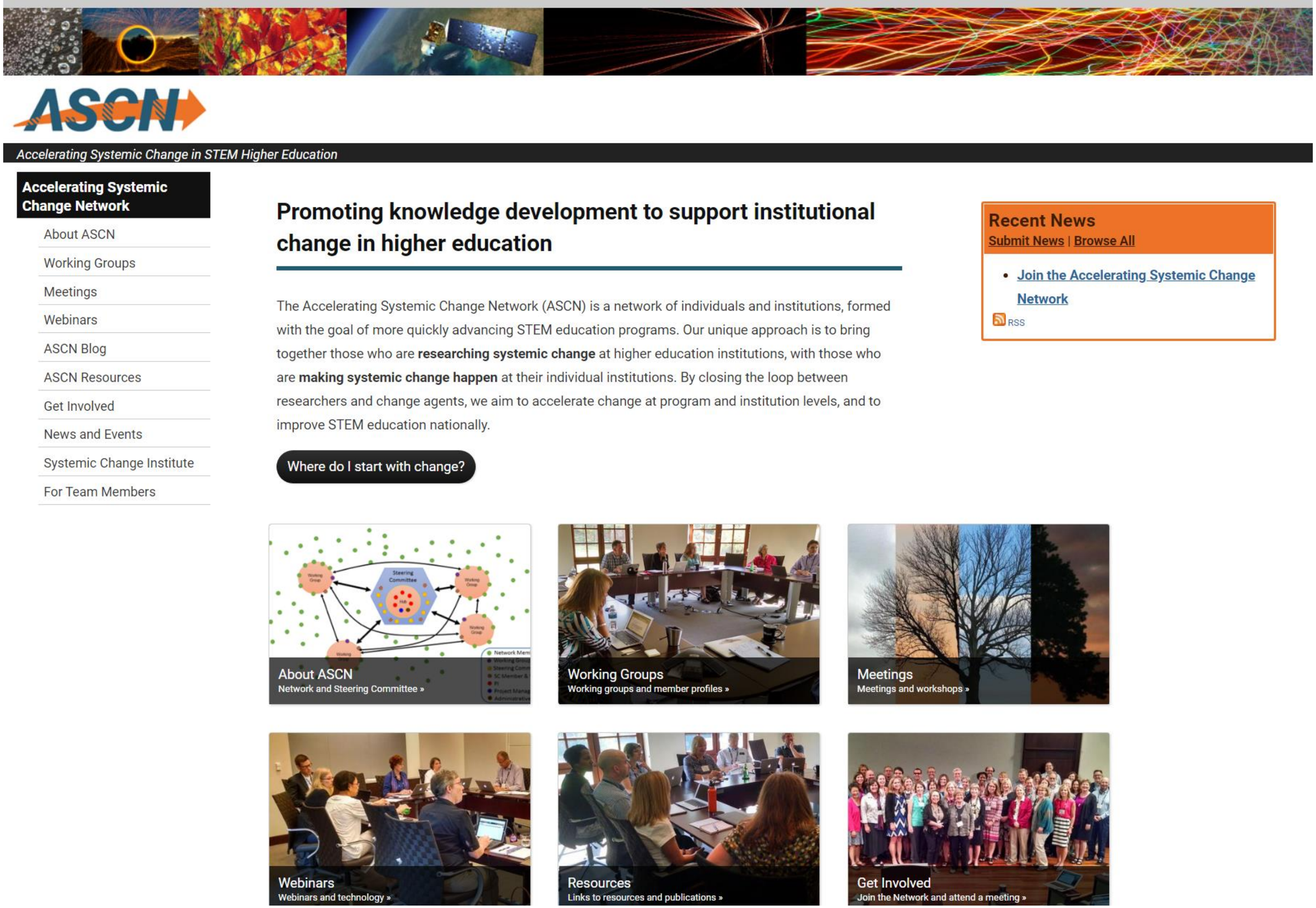
Communities of Transformation (CoTs)

1. Novel approach to improving STEM education
2. Address both individual faculty and broader systemic change
3. Benefits of these communities accrue to both individual faculty and to their institutions
4. Provide significant benefits for women faculty and faculty of color
5. Positive outcomes follow from an engaging philosophy that is lived in programmatic activities and fostered through a supportive and mentoring community.
6. Follow similar trajectories as the evolve from an idea to a community.
7. Face common challenges and must develop particular strategies to navigate them.
8. Rely on a specific set of avenues for expanding impact.
9. Future CoTs can draw on the sustainability model identified and developed through this study.
10. There are further ways that CoTs can extend their impact.

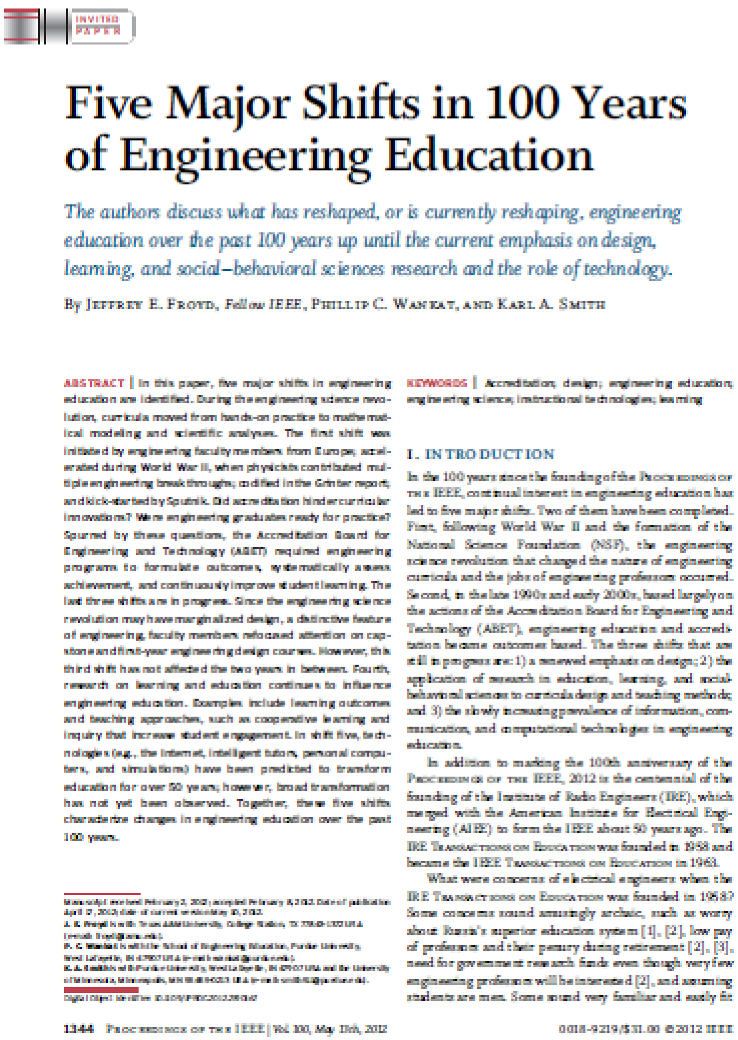
https://pullias.usc.edu/download/communities-of-transformation-and-their-work-scaling-stem-reform/

Table 4.1: Comparison of Core Characteristics of Communities of Practice, Professional Learning Communities, and Communities of Transformation

Characteristic	Community of Practice	Professional Learning Community	Community of Transformation
Definition	Group of individuals who share a concern or a passion for something they do and learn how to do it better as they interact regularly.	Group of individuals committed to working collaboratively in ongoing processes of collective inquiry and action research to achieve better results.	Distributed community of individuals that uses a core philosophy to create and foster new practices that can be integrated into the various institutions in which individuals work.
Underlying characteristics	A domain, a community, and a practice that is shared across participants.	A well-defined domain, a hierarchical and structured community, and often not a clear, shared practice.	An innovation that is lived (domain), a distributed community, and a practice (e.g., teaching STEM).
Membership and domain	Identity is defined by a shared domain of interest in current practices. Membership implies a commitment to the domain, and a shared competence that distinguishes members from others. Members are practitioners who develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems, etc.	Membership is defined often by a leader who created the community; thus, the identity of the PLC comes jointly from the domain as well as from the leader. In education PLCs, the domain is typically student success. The notion of a shared practice may not be a prevalent part of this model.	Shared interest or domain is an innovation that does not currently exist in practice in a substantial way; members are organized around the task of bringing this vision into practice. Membership is organic, as in CoPs, and there is a shared practice (i.e.. teaching).
Community	Members engage in joint activities and discussions, help each other, and share information. They build relationships that enable them to learn from one another. The focus is on improvement of the domain. Traditionally, CoPs have been physically located in one place and have expanded over time.	Membership is steered toward the explicit task of bringing together teachers and administrators, or other hierarchically defined practitioners. Across this hierarchy, a sense of collective work is emphasized, such as efforts toward renewal or improvement of a school.	Members engage in joint activities and helpful discussions mostly shared at a distance. Their relationships enable them to learn or share from each other. The focus is on engagement and absorption of a novel practice. Communities rely on a hybrid structure with some in-person encounters, relying mostly on distance interactions. These communities are less organic than CoPs and less structured than PLCs.
Actions	Problem-solve, share information, seek and foster expertise, visit others, map knowledge.	Discuss teacher work, discuss student work, discuss student data, discuss the professional literature.	Hold signature events that demonstrate the new innovations; develop leadership that embodies this new goal; develop a guiding philosophy that helps support the new practices; create a guiding document.
Research background	Lave and Wenger's concept of situated learning, developed while studying apprenticeship as a learning mode.	Evolution of Lave and Wenger into a highly structured, constructed, and hierarchical form of situated learning.	Further evolution of Lave and Wenger, not situated in day-to-day practice, but in a distributed community. Development of idea of community that is neither fully organic nor highly constructed.
Where applied	CoPs have been adopted most readily in business due to the recognition that knowledge is a critical asset that needs to be managed strategically. Also seen across multiple sectors (government, non-profit) and professions like academe and law.	PLCs are mostly used in schools and in other more hierarchical institutions. Also found in other professions.	To date, CoTs have only been identified in higher education, but they are likely to exist in other places. They are most likely to be useful in settings or domains where a deep or fundamental change in practice is needed or already taking place.



https://ascnhighered.org/index.html



INVITED PAPER

Five Major Shifts in 100 Years of Engineering Education

The authors discuss what has reshaped, or is currently reshaping, engineering education over the past 100 years up until the current emphasis on design, learning, and social–behavioral sciences research and the role of technology.

By Jeffrey E. Froyd, *Fellow IEEE*, Phillip C. Wankat, and Karl A. Smith

1344 Proceedings of the IEEE | Vol. 100, May 13th, 2012

0018-9219/$31.00 ©2012 IEEE

1. a shift from hands-on and practical emphasis to engineering science and analytical emphasis;
2. a shift to outcomes-based education and accreditation;
3. a shift to emphasizing engineering design;
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5. a shift to integrating information, computational, and communications technology in education.

Current Shift – Remote Learning

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&tp=&arnumber=6185632

Remote Learning: Emphasize Big Ideas (Enduring Outcomes)*

- How People Learn
- Streamlined Course Design
  - Alignment of Outcomes, Assessment and Instruction
- Interactive Learning

*See Streveler and Smith (2020), Course design in the time of coronavirus: Put on your designer's CAP. *Advances in Engineering Education*.

https://advances.asee.org/opinion-course-design-in-the-time-of-coronavirus-put-on-your-designers-cap/

Learning Requires*

deliberate

distributed

practice

***Thanks to Ruth Streveler for these slides**

Also see Brown, P.C., Henry L. Roediger III, H.L., & Mark A. McDaniel, M.A. (2014). *Make It Stick: The Science of Successful Learning*. Belknap Press: An Imprint of Harvard University Press

Key Implications

Deliberate

Attention must be paid

Attention and processing power = cognitive load (bandwidth)

- LIMITED – need to be careful how one uses the learner's bandwidth
  - Link to Curricular Priorities
- Continuous partial attention

- Reflection is needed
  - Need for feedback
    - Link to assessment

Creative Performance From Students (& Faculty) Requires Maintaining a Creative Tension Between

Challenge and Security

Pelz, Donald, and Andrews, Frank. 1966. Scientists in Organizations: Productive Climates for Research and Development. Ann Arbor: Institute for Social Research, University of Michigan.

Pelz, Donald. 1976. Environments for creative performance within universities. In Samuel Messick (Ed.), Individuality in learning, pp. 229-247. San Francisco: Jossey-Bass

Edmonson, A.C. 2008. The competitive advantage of learning. Harvard Business Review 86 (7/8): 60-67.

Accountability for Meeting Demanding Goals

Psychological Safety	LOW	HIGH
HIGH	**Comfort zone** Employees really enjoy working with one another but don't feel particularly challenged. Nor do they work very hard. Some family businesses and small consultancies fall into this quadrant.	**Learning zone** Here the focus is on collaboration and learning in the service of high-performance outcomes. The hospitals described in this article fall into this quadrant.
LOW	**Apathy zone** Employees tend to be apathetic and spend their time jockeying for position. Typical organizations in this quadrant are large, top-heavy bureaucracies, where people fulfill their functions but the preferred modus operandi is to curry favor rather than to share ideas.	**Anxiety zone** Such firms are breeding grounds for anxiety. People fear to offer tentative ideas, try new things, or ask colleagues for help, even though they know great work requires all three. Some investment banks and high-powered consultancies fall into this quadrant.

Key Implications

Distributed

Repetition <u>over time</u>

- Spaced vs. massed practice*
- Spiral curriculum

Multiple modes of input

- Visual
- Audio
- Kinesthetic
- Self-explanation
- Explaining to others

*Kandel, E.B. 2007. In Search of Memory: The Emergence of a New Science of Mind. New York: Norton.

Key Implications

Practice what you want to learn

Attentive – doing something

Constructive – adding to your prior knowledge

Interactive – working with others to add to your prior knowledge

Chi, M.T.H. 2009. Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science 1*, 73–105.

I-C-A-P Framework

~~ACTIVE~~ ATTENTIVE	CONSTRUCTIVE	INTERACTIVE
Doing something physically Paying Attention	Producing outputs that go beyond presented information	Dialoguing substantively on the same topic, and not ignoring a partner's contribution
Engaging activities	Self-construction	Guided-construction
Attending processes	Creation processes	Joint creation processes

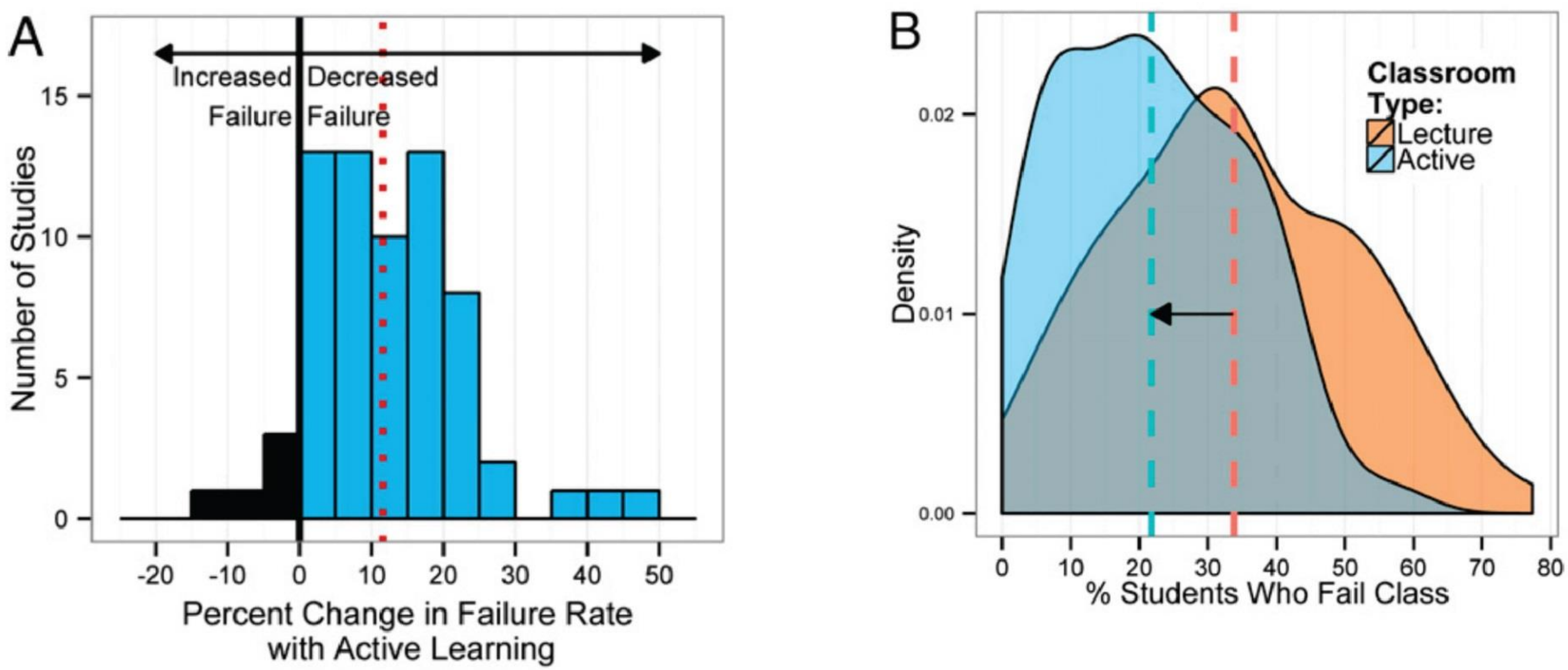
Interactive > Constructive > Attentive > Passive

ICAP framework, Michelene T.H. Chi

Chi, M.T.H. (2009). Active-Constructive-Interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*, 73-105

Engaged Pedagogies = Reduced Failure Rates

Evidence-based research on learning indicates that when students are actively involved in their education they are more successful and less likely to fail. A new PNAS report by Freeman et al., shows a significant decrease of failure rate in active learning classroom compared to traditional lecture



Freeman, Scott; Eddy, Sarah L.; McDonough, Miles; Smith, Michelle K.; Okoroafor, Nnadozie; Jordt, Hannah; Wenderoth, Mary Pat; Active learning increases student performance in science, engineering, and mathematics, 2014, Proc. Natl. Acad. Sci.

The Engineering Design Process vs. Streamlined Course Design Process

Engineering Design

- Determine requirements/ specifications
- Develop or use established metrics to measure against outcomes
- Plan and develop process, system, etc. to implement

Streamlined Course Design Process

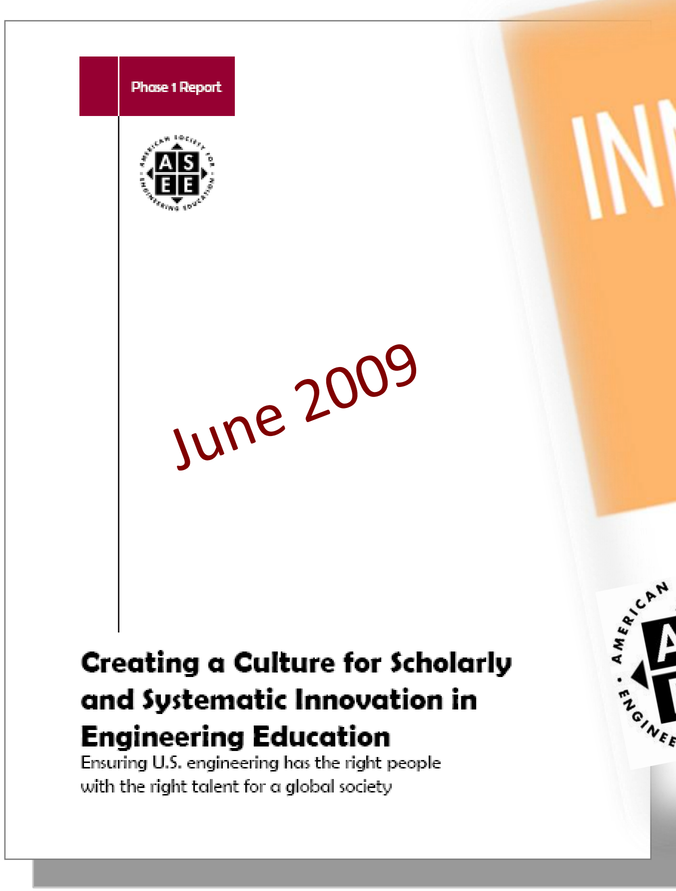
- Identify the desired results
- Determine acceptable evidence
- Plan learning experiences

"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; Former Dean, Provost and President of the University of Michigan

ASEE Reports - A Path Forward



June 2009

June 2012

Seven Recommendations for Innovation with Impact

Who

1. Grow professional development in teaching and learning.
2. Expand collaborations.

What

3. Expand efforts to make engineering more engaging, relevant, and welcoming.

How

4. Increase, leverage, and diversify resources for engineering teaching, learning, and innovation.
5. Raise awareness of proven practices and of scholarship in engineering education.

Seven Recommendations for Innovation with Impact *(continued)*

Creating a Better Culture

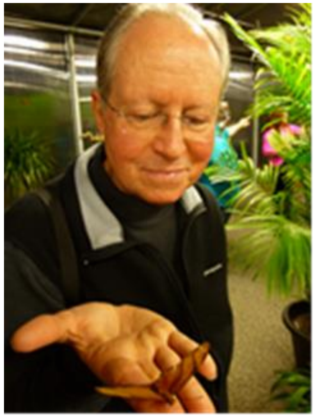
To measure progress in implementing policies, practices, and infrastructure in support of scholarly and systematic innovation in engineering education:

6. Conduct periodic self-assessments in our individual institutions.
7. Conduct periodic community-wide self-assessments.

https://www.asee.org/member-resources/reports/Innovation-with-Impact

Thank you!

An e-copy of this presentation will be posted to:
https://karlsmithmn.org/engineering-education-research-and-innovation/



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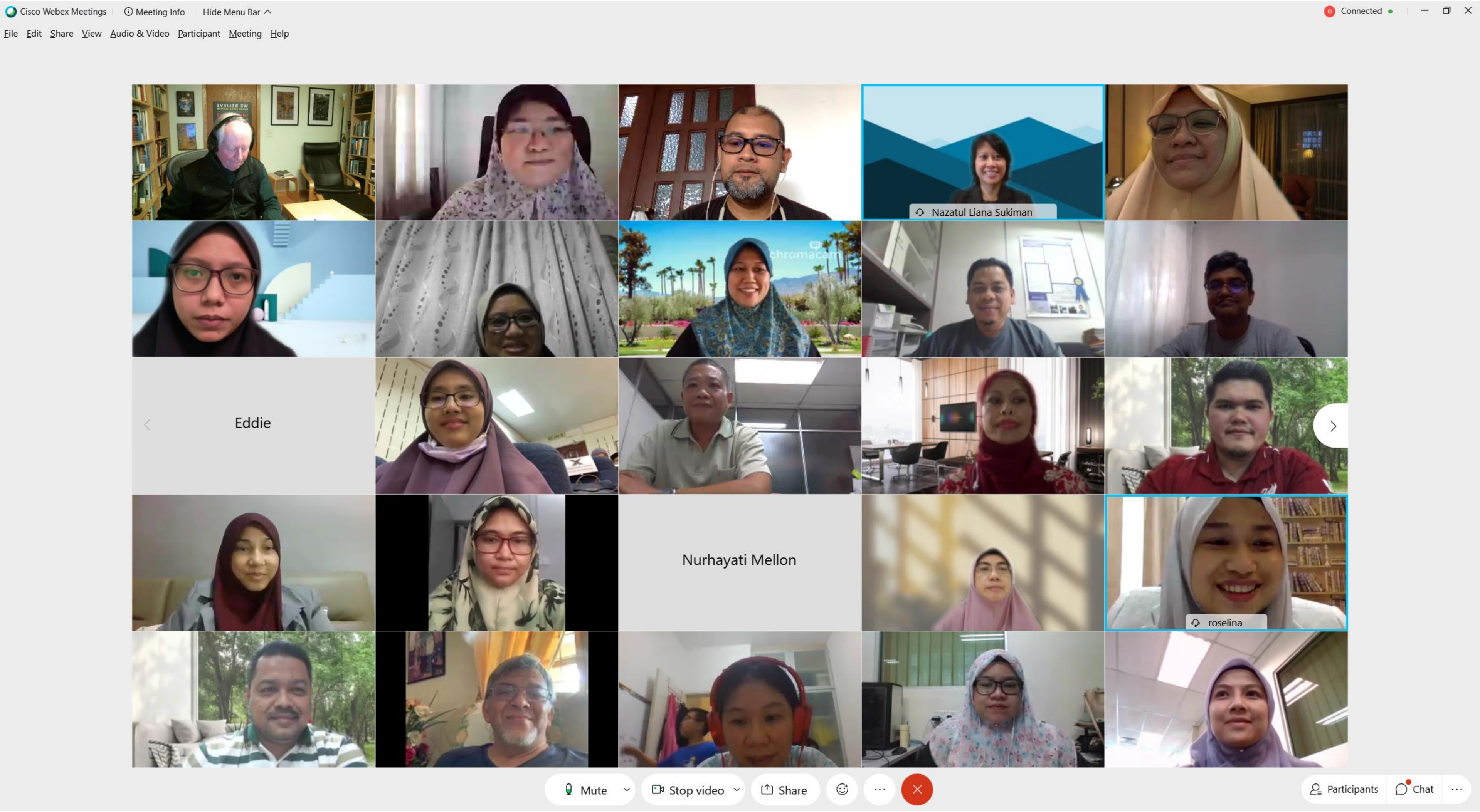
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