Building Engineering Education Research Capabilities

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Engineering Education: Practices and Implementation
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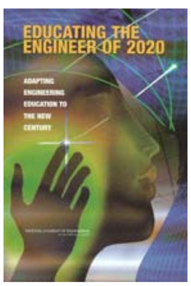
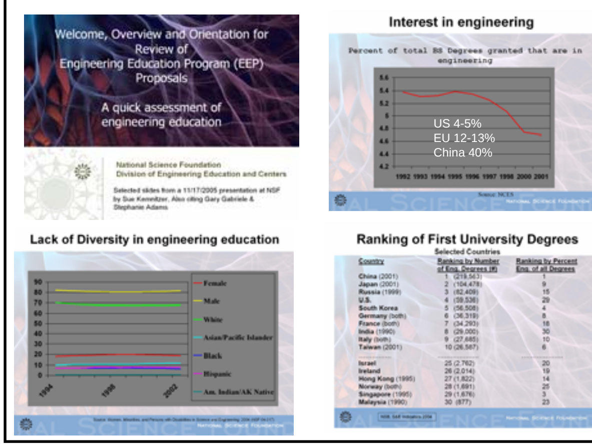
Building Engineering Education Research Capabilities: Overview

- Why Bother? Why Now?
  - ABET/ASEE/Carnegie Foundation/NAE/NSF Emphasis
  - Globalization
    - Outsourcing of Engineering
    - Engineering Capabilities
  - Demographics
    - Interest in Engineering
    - Current Workforce
  - Learning Sciences Research, e.g., expertise
- Engineering Education as a Field of Research
  - Features of Scholarly and Professional Work
  - Characteristics of Disciplines – Kuhn & Fensham
- Current Activities – NSF/NAE/Departments of Engineering Education

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.



The reports…

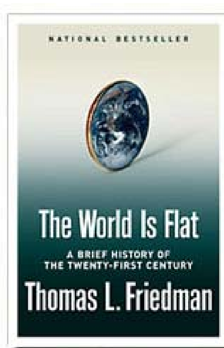
- *Engineering Research and America's Future* (NAE, 2005): Committee to Assess the Capacity of the U.S. Engineering Research Enterprise


- *The Engineer of 2020* (NAE, 2004) and *Educating the Engineer of 2020* (NAE, 2005)

- *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (NRC/COSEPUP, 2005)

- *Innovate American: National Innovation Initiative Final Report* (Council on Competitiveness, 2005)

National Science Foundation



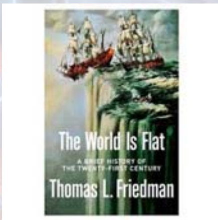
Platform for Collaboration (1st Three Flatteners):
1. 11/9/89
2. 8/9/95
3. Work Flow Software

Horizontalize

NYTimes MAGAZINE April 3, 2005
It's a Flat World, After All
By THOMAS L. FRIEDMAN

Video – Think Global Series:
http://minnesota.publicradio.org/radio/features/2005/05/collaboration/

The World is Flat



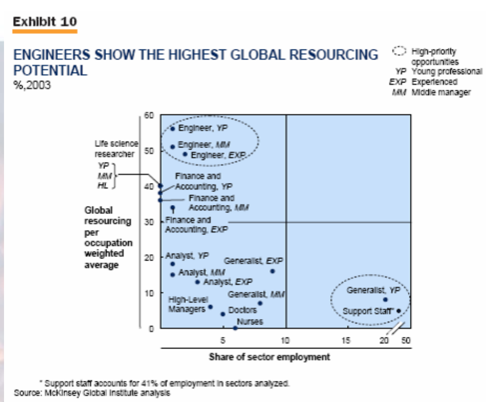
"Clearly, it is now possible for more people than ever to collaborate and compete in real-time, with more people, on more kinds of work, from more corners of the planet, and on a more equal footing, than at any previous time in the history of the world"

Emerging Global Labor Market

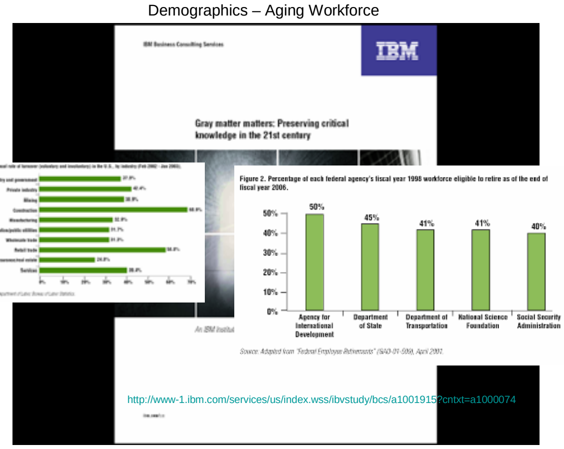
- Engineering occupations are the most amenable to remote location
- Offshore talent exceeds high-wage countries' potential by a factor of 2
- 17% of engineering talent in low-wage countries is suitable* for work in a multinational company.
- At current suitability rates, and an aggressive pace of adoption in demand, supply of engineers could be constrained by 2015.

"The Emerging Global Labor Market"

*Suitable = quality of education, location, domestic competition



Demographics – Aging Workforce



http://www-1.ibm.com/services/us/index.wss/ibvstudy/bcs/a1001915?cntxt=a1000074

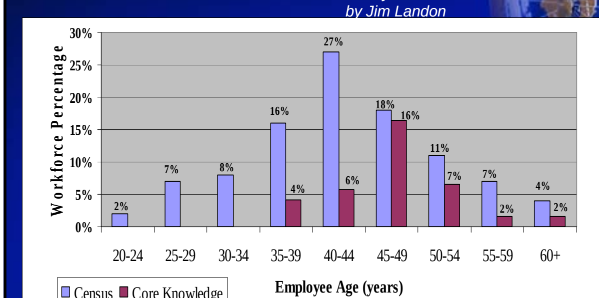
Creating and Preserving What We Know

A Knowledge Management Plan and Implementation for Honeywell by Jim Landon

Capstone Project
MOT 2003

Base of Experience

Creating and Preserving What we Know: A Knowledge Management Plan and Implementation for Honeywell CAP by Jim Landon

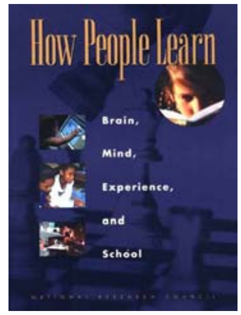


Strategy Proposal

- Embrace Knowledge Management as a unified, operational strategy for CAP Engineering and Technology department

Center on Four tactical cornerstones

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.

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

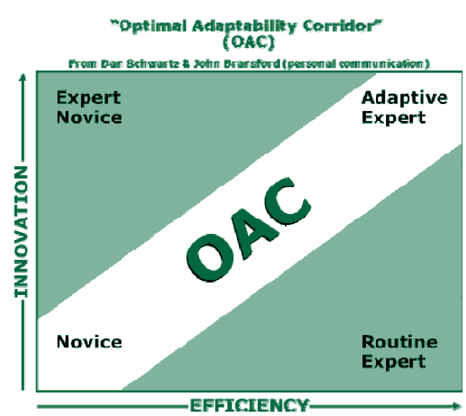
Classic Studies in Expertise Research

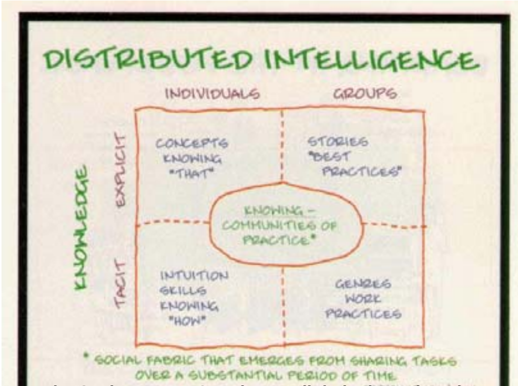
- Fitts and Posner (1967) - model with three phases and for acquiring acceptable (not expert) performance
- Simon and Chase (1973) - theory of expertise acquisition where time spent leads to acquisition of patterns, chunks, and increasingly-complex knowledge structures
- Ericsson and Smith (1991) - expert performance must be studied with individuals who can reliably and repeatedly demonstrate superior performance
- Ericsson, Krampe, & Tesche-Romer (1993) - expert levels of performance are acquired gradually over time through use of deliberate practice and are mediated by mental representations developed during the deliberate practice period

Stages of Skill Acquisition

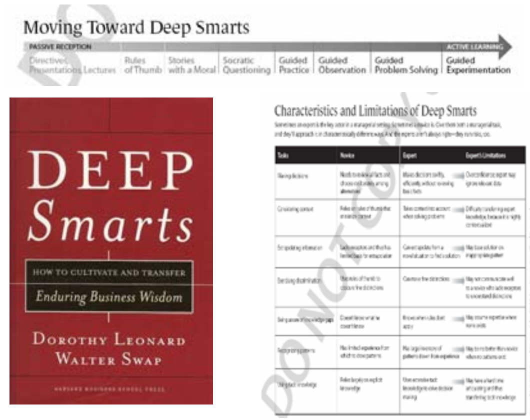
(Dreyfus & Dreyfus, 1986, Mind over machine: The power of human intuition and expertise in the era of the computer, p. 50)

Skill Level	Components	Perspective	Decision	Commitment
1. Novice	Context-free	None	Analytical	Detached
2. Advanced Beginner	Context-free and Situational	None	Analytical	Detached
3. Competent	Context-free and Situational	Chosen	Analytical	Detached understanding and deciding. Involved in outcome
4. Proficient	Context-free and Situational	Experienced	Analytical	Involved understanding Detached deciding
5. Expert	Context-free and Situational	Experienced	Intuitive	Involved





John Seely Brown. Growing up digital: The web and a new learning ecology. Change, March/April 2000.



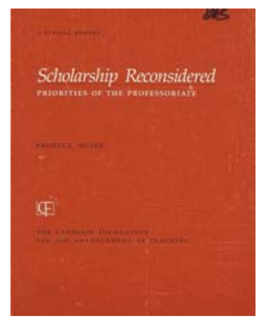
Leonard, Dorothy & Swap, Walter. 2004. Deep Smarts. *Harvard Business Review,* September

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.

Scholarship Reconsidered: Priorities of the Professoriate Ernest L. Boyer

- The **Scholarship of Discovery**, research that increases the storehouse of new knowledge within the disciplines;
- The **Scholarship of Integration**, including efforts by faculty to explore the connectedness of knowledge within and across disciplines, and thereby bring new insights to original research;
- The **Scholarship of Application**, which leads faculty to explore how knowledge can be applied to consequential problems in service to the community and society; and
- The **Scholarship of Teaching**, which views teaching not as a routine task, but as perhaps the highest form of scholarly enterprise, involving the constant interplay of teaching and learning.



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

The Basic Features of Scholarly and Professional Work

1. Requires a high level of discipline-related expertise;
2. Is conducted in a scholarly manner with clear goals, adequate preparation, and appropriate methodology;
3. Has significance beyond the setting in which the research is conducted;
4. Is innovative;
5. Can be replicated or elaborated on;
6. Is appropriately and effectively documented, including a thorough description of the research process and detailed summaries of the outcomes and their significance;
7. Is judged to be meritorious and significant by a rigorous peer review process.

Adapted from: Diamond and Adam (1993) and Diamond (2002).

Engineering Education as a Field of Research

Journal of Engineering Education: Guest Editorials

- Felder, R.M., S.D. Sheppard, and K.A. Smith, "A New Journal for a Field in Transition," *Journal of Engineering Education*, Vol. 93, No. 1, 2005, pp. 7–12.
- Kerns, S.E., "Keeping Us on the Same Page," *Journal of Engineering Education*, Vol. 93, No. 2, 2005, p. 205.
- Gabriele, G., "Advancing Engineering Education in a Flattened World," *Journal of Engineering Education*, Vol. 94, No. 3, 2005, pp. 285–286.
- Haghighi, K., "Quiet No Longer: Birth of a New Discipline," *Journal of Engineering Education*, Vol. 94, No. 4, 2005, pp. 351–353.
- Fortenberry, N.L., "An Extensive Agenda for Engineering Education Research," *Journal of Engineering Education*, Vol. 95, No. 1, 2006,pp. 3–5.
- Streveler, R. A. and K.A. Smith, "Conducting Rigorous Research in Engineering Education," *Journal of Engineering Education*, Vol. 95, No. 2, 2006.
- Wormley, D.N. "A Year of Dialogue Focused on Engineering Education Research," *Journal of Engineering Education*, Vol. 95, No. 3, 2006.

Fensham, P.J. 2004. *Defining an identity.* The Netherlands: Kluwer

CRITERIA FOR A FIELD

1. **Structural Criteria**
   1. Academic recognition
   2. Research journals
   3. Professional associations
   4. Research conferences
   5. Research centers
   6. Research training
2. **Intra-Research Criteria**
   1. Scientific knowledge
   2. Asking questions
   3. Conceptual and theoretical development
   4. Research methodologies
   5. Progression
   6. Model publications
   7. Seminal publications
3. **Outcome Criteria**
   1. Implications for practice

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)
- Engineering Education Research Colloquies (EERC)

Departments of Engineering Education

- Purdue University - https://engineering.purdue.edu/ENE/
- Virginia Tech - http://www.enge.vt.edu/main/index.php
- Utah State University - http://www.engineering.usu.edu/ete/

Annals of Research on Engineering Education (AREE)

- Link journals related to engineering education
- Increase progress toward shared consensus on quality research
- Increase awareness and use of engineering education research
- Increase discussion of research and its implications

- Resources – community recommended
  - Annotated bibliography
  - Acronyms explained
  - Conferences, Professional Societies, etc.
- Articles – education research
  - Structured summaries
  - Reflective essays
  - Reader comments

www.areeonline.org

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

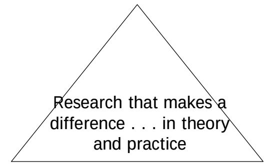
NSF-CCLI-ND
American Society for Engineering Education
Karl Smith & Ruth Streveler
University of Minnesota/Purdue University &
Colorado School of Mines/Purdue University

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)

Engineering Education Research

Theory



Research Practice

Cooperative Learning

Kurt Lewin - Social Interdependence Theory (~1935)

1. The essence of a group is the interdependence among members (created by common goals) which results in the group being a "dynamic whole" so that a change in the state of any member of subgroup changes the state of any other member or subgroup
2. An intrinsic state of tension within group members motivates movement toward the accomplishment of the desired common goals.

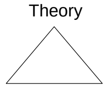
Student – Student Interaction Lewin's Contributions

- 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"

Cooperative Learning

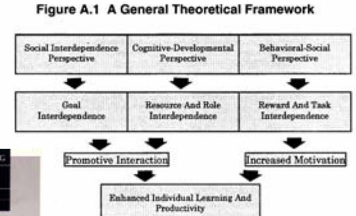
- Theory – Social Interdependence – Lewin – Deutsch – Johnson & Johnson
- Research – Randomized Design Field Experiments
- Practice – Formal Teams/Professor's Role

Theory



Research Practice

Figure A.1 A General Theoretical Framework



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

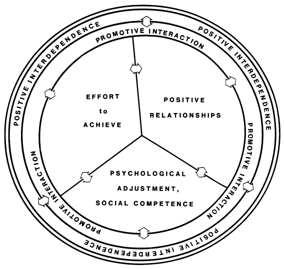
Cooperative Learning Research Support

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



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.

Research Inspired By:

Use (Applied)

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

Stokes, Donald. 1997. Pasteur's quadrant: Basic science and technological innovation. Wash, D.C., Brookings.

Engaged Scholarship

1. Design the project to addresses a big question or problem that is grounded in reality.
2. Design the research project to be a collaborative learning community.
3. Design the study for an extended duration of time.
4. Employ multiple models and methods to study the problem.
5. Re-examine assumptions about scholarship and roles of researchers.

"Knowledge For Theory and Practice" by Andrew H. Van de Ven and Paul E. Johnson. Carlson School of Management, University of Minnesota, *Academy of Management Review,* October 2006

Boyer, Ernest L. 1990. *Scholarship reconsidered: Priorities for the* professoriate. Princeton, NJ: The Carnegie Foundation for the Advancement of Teaching.

Diamond, R., "The Mission-Driven Faculty Reward System," in R.M. Diamond, Ed., *Field Guide to Academic Leadership*, San Francisco: Jossey-Bass, 2002

Diamond R. & Adam, B. 1993. Recognizing faculty work: Reward systems for the year 2000. San Francisco, CA: Jossey-Bass.

National Research Council. 2002. *Scientific research in education*. Committee on Scientific Principles in Education. Shavelson, R.J., and Towne, L., Editors. Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.

Centers for Learning and Teaching Network. http://cltnet.org/cltnet/index.jsp

Shulman, Lee S. 1999. Taking learning seriously. Change, 31 (4), 11-17.

Wankat, P.C., Felder, R.M., Smith, K.A. and Oreovicz, F. 2002. The scholarship of teaching and learning in engineering. In Huber, M.T & Morreale, S. (Eds.), Disciplinary styles in the scholarship of teaching and learning: A conversation. Menlo Park, California: American Association for Higher Education and the Carnegie Foundation for the Advancement of Teaching, 2002, pp. 217–237.

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