Research Areas and Topics in Engineering Education

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Research Areas and Topics in Engineering Education

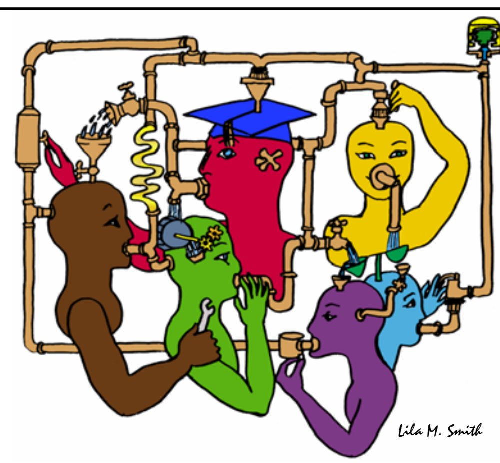
- **Research Questions**
  - Internal Quandaries
  - External Pressures
    - ABET/NSF/NAE/Carnegie Foundation
    - Demographics
      - Interest in Engineering
      - Current Workforce
    - Globalization
      - Outsourcing of Engineering
      - Engineering Capabilities
- Engineering Education as a Field of Research
  - Features of Scholarly and Professional Work
  - Characteristics of Disciplines – Kuhn & Fensham
- Building Engineering Education Research Capabilities – Current Activities – NSF/NAE

First Teaching Experience

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

Engineering Education

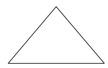
- Practice – Dismal failure!
- Research – ?
- Theory – ?



Cooperative Learning

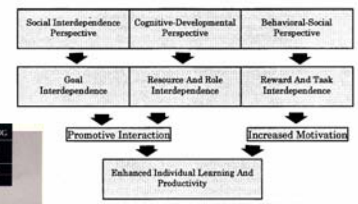
- Theory – Social Interdependence – Lewin – Deutsch – Johnson & Johnson
- Research – Empirical Support - Randomized Design Field Experiments
- Practice – Formal Teams/Professor's Role

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

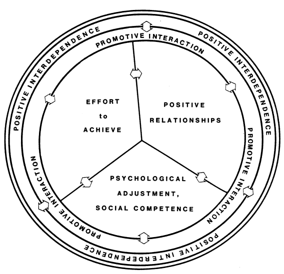
Cooperative Learning Research Support

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



Pedagogies of Engagement: Classroom-Based Practices

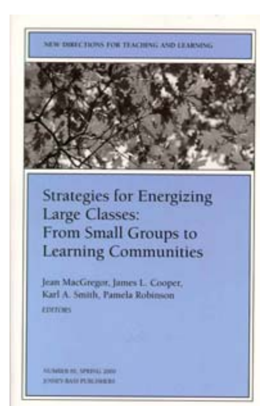
http://www.asee.org/about/publications/jee/upload/2005jee_sample.htm

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.



Strategies for Energizing Large Classes: From Small Groups to Learning Communities:

Jean MacGregor, James Cooper, Karl Smith, Pamela Robinson

New Directions for Teaching and Learning, No. *81*, 2000. Jossey- Bass

Engineering Education Research and Practice – Your Story

- Individually reflect on your interest in engineering education
- Identify critical incidents or marker events that influenced your interest
- Turn to the person next to you, introduce yourselves and talk about your stories

Continuum of Engineering Education Research Practice

- Teach as Taught
- Excellent Teacher
- Scholarly Teacher
- Scholarship of Teaching and Learning (SoTL)
- Engineering Education Research

Scholarly Teaching and the Scholarship of Teaching and Learning*

- Scholarly teaching: The instructor
  - (a) is aware of modern pedagogical developments and incorporates them in his/her teaching where appropriate
  - (b) reflects on, assesses, and attempts to improve his/her teaching (classroom research)
- Scholarship of teaching and learning: Research, publication, possibly grants on work related to education

*Shulman & Hutchings

Why do SoTL?

- Fosters significant, long-lasting learning for all students
- Enhances practice and profession of teaching
- Brings faculty's work as teachers into the scholarly realm.

CASTL project purposes http:www.aahebulletin.com

Types of Questions

- Instructional Knowledge—components of instructional design
- Pedagogical Knowledge—student learning & how to facilitate it
- Curricular Knowledge—goals, purposes & rationales for courses or programs

3 types of reflection within each form of knowledge

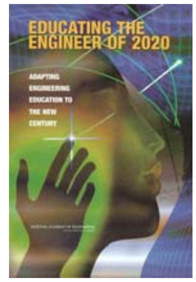
- Content—What should I do…
- Process—How did I do…
- Premise—Why does it matter…

Examples for process reflection:

How did I (we) do at:

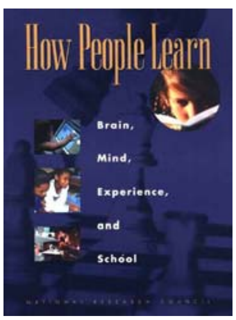
- Course design, methods & assessing effectively? (instructional)
- Facilitating student knowledge? Was I successful? (pedagogical)
- Arriving at goals & rationale for courses? (curricular)

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.

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

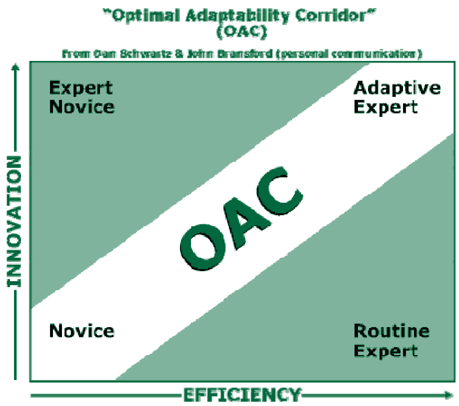
Classic Studies in Expertise Research

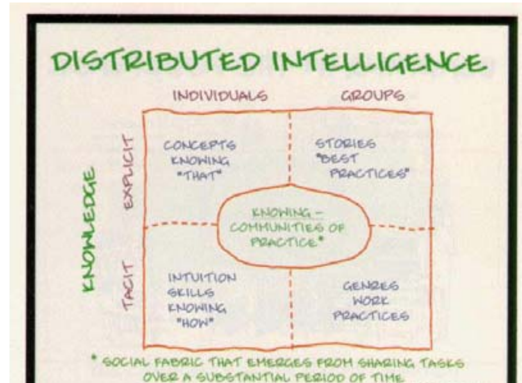
- Fitts and Posner (1967) - model with three phases and for acquiring acceptable (not expert) performance
- Simon and Chase (1973) - theory of expertise acquisition where time spent leads to acquisition of patterns, chunks, and increasingly-complex knowledge structures
- Ericsson and Smith (1991) - expert 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.

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.

Research Areas and Topics in Engineering Education

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    - ABET/NSF/NAE/Carnegie Foundation
    - Demographics
      - Interest in Engineering
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    - Globalization
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  - Features of Scholarly and Professional Work
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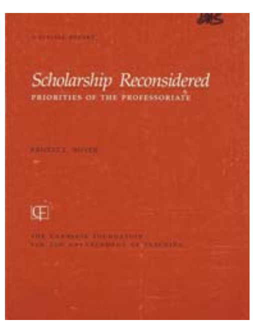
Scholarship Reconsidered: Priorities of the Professoriate Ernest L. Boyer

- 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.



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.

Four components of a "disciplinary matrix"

1. shared theories
2. models
3. values (accurate and quantitative predictions)
4. exemplars (concrete problem-solutions).

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

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  - Features of Scholarly and Professional Work
  - Characteristics of Disciplines – Kuhn & Fensham
- **Building Engineering Education Research Capabilities – Current Activities – NSF/NAE**

Building Engineering Education Research Capabilities:

- NSF Initiated Science and Engineering Education Scholars Program (SEESP)
- 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)

SEESP Background

- National Science Foundation initiated at
  - Georgia Tech
  - University of Wisconsin – Madison
  - Carnegie Mellon University
  - Stanford University
  - Syracuse University
- UW Madison – SEESP continued by CIC Graduate School and Engineering Deans
  - UW Madison – 1996 -1999
  - UIUC – 2000
  - Minnesota – 2001, 2002
  - Penn State – 2004, 2005
  - Howard University – 2006, 2007
  - Vanderbilt University – 2008

SEESP Program Objectives:

- Strengthen preparation as teachers of undergraduate students and, thereby, strengthen skills for the competitive job market in higher education;
- Understand undergraduate students and especially appreciate diversity in terms of cultural background, age, gender, interests, and learning styles;
- Improve teaching methods and examine the learning process;
- Embrace future responsibilities for leadership in higher education; and
- Develop confidence in becoming "change agents" at local institutions to create effective learning environments for students and faculty.

Participant Response

- Quote:
  - "I truly believe that the week last summer in Minnesota was the most valuable time I have spent as a new faculty member, particularly in the area of teaching. The knowledge gained from the program would have probably taken me several years to learn through experience, the hard way! Incorporating several teaching and learning ideas from the workshop (active learning, quick feedback, incorporating exercises and small group work in a lecture setting, "minute quizzes") has drastically improved my abilities and interest in teaching and learning. As a result, student evaluations of my teaching have gone from dismal (winter semester before SEESP) to great (past fall semester after SEESP)!"

Key - Changing the People:

Engineering Education Scholars Workshops*

Vision

*To cultivate a new generation of engineering faculty dedicated to the lifelong pursuit of integration and excellence in **teaching** and **research***

* **The term "education scholar" conveys the notion that the scholarship of knowledge transfer is intertwined with and equal in importance to that of knowledge creation.**

Marshall Lih, 2002

CAEE Vision for Engineering Education

Center for the Advancement of Engineering Education
Cindy Atman, Director

CAEE Team

University of Washington
Colorado School of Mines
Howard University
Stanford University
University of Minnesota

CAEE Affiliate Organizations

City College of New York (CCNY), Edmonds Community College, Highline Community College (HCC), National Action Council for Minorities in Engineering (NACME), North Carolina A&T (NCA&T), San Jose State University (SJSU), University of Texas, El Paso (UTEP), Women in Engineering Programs & Advocates Network (WEPAN) and Xavier University

CAEE - Elements for Success

- Scholarship on Learning Engineering
  Learn about the engineering student experience
- Scholarship on Engineering Teaching
  Help faculty improve student learning
- Institute for Scholarship on Engineering Education
  Cultivate future leaders in engineering education

CAEE Approach

Theory

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

Research

Practice

NCETE Overview

- National Center for Engineering and Technology Education (NCETE) is an NSF-funded Center for Learning and Teaching
  - Funded on September 15, 2004
  - One of 18 CLT's in the country
  - NCETE is the only CLT focused on engineering and technology education
  - NCETE is the only CLT with 9 partner institutions
  - $10M over 5 years with a required 18-month reverse site visit

national center for engineering and technology education

NCETE Overview

CLT Goals:

•Renew and diversify the cadre of leaders in STEM education, particularly the *higher education faculty* who educate STEM teachers and professionals in leadership positions at state and district-levels and other education organizations

•Enhance the content knowledge and pedagogical skills of current and future elementary and secondary teachers; and

•Support research into STEM education issues of national import.

national center for engineering and technology education

NCETE Overview

•NCETE's ultimate goal is to infuse engineering design and problem solving into technology education in grades 9-12

•Team engineering faculty with technology educators

national center for engineering and technology education

NCETE Overview

- Build a community of researchers and leaders to conduct research in emerging engineering and technology education areas
  - •Recruit and retain 20 doctoral fellows
  - •Develop and teach shared core courses
- Prepare technology education teachers at the BS and MS level who can infuse engineering design and problem solving into the 9-12 grade curriculum (current and future)
  - •Professional development experiences
  - •Refocus the pre-service experience
- Create a body of research that improves our understanding of learning and teaching engineering and technology subjects
  - •RFP process

national center for engineering and technology education

Center for the Integration of Research, Teaching, and Learning (CIRTL)

NSF Center for Learning and Teaching

University of Wisconsin - Madison
Michigan State University
Pennsylvania State University

…develop a national STEM faculty …

UNDERGRADS

Community College
Liberal Arts
HBCU
Masters University
Comprehensive Univ.
Research University

Research Universities

100 RUs => 80% Ph.D's

FACULTY

Community College
Liberal Arts
HBCU
Masters University
Comprehensive Univ.
Research University

CIRTL Mission

To promote a
a national STEM faculty
committed to implementing and advancing
effective teaching practices
for diverse student audiences
as part of their professional careers.

Teaching-as-Research

"The nation must develop STEM faculties who themselves continuously inquire into their students' learning."

- Engagement in teaching as engagement in STEM research
  - Hypothesize, experiment, observe, analyze, improve
- Aligns with skills and inclinations of graduates-through-faculty, and fosters engagement in teaching reform
- Leads to self-sustained improvement of STEM education

Learning Communities

"Rich, enduring, integrative environments for change in learning and teaching … learning communities are life-changing."

- Provide community with shared values of learning, teaching, and professional development
- Blend diverse participants and levels of participation.
- Develop strong relationships that are a foundation for institutional and national change.

Diversity

"Many STEM faculty are not aware of the diversity of their students and thus do not design their teaching practice to respond to them."

- STEM faculty are teaching ever more diverse student populations.
- Mounting research shows the pivotal role of classroom experiences on student learning and persistence.
- Thread teaching and learning with diverse student audiences through every facet of the learning community.

NATIONAL ACADEMY OF ENGINEERING
OF THE NATIONAL ACADEMIES
CENTER FOR THE ADVANCEMENT OF SCHOLARSHIP ON ENGINEERING EDUCATION

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A Work-in-Progress: NAE Center for the *Advancement* of Scholarship on Engineering Education

Norman L. Fortenberry, Sc.D.
Director, CASEE
http://www.nae.edu/CASEE
nfortenb@nae.edu
(202) 334-1926

November 8, 2003

CASEE

NAE and Education– Wm. A. Wulf's 4-legged stool

1999, established the Committee on Engineering Education
- Stream of reports, workshops, etc. of intrinsic value
- Implicit, repeated message that NAE values engineering education

2000, reinterpreted NAE membership criteria to better recognize contributions to engineering

2001, initiated the Bernard M. Gordon Prize for Innovation in Engineering and Technology Education
- $500,000 on par with Draper (engineering and society) and Russ (bioengineering) Prizes

October 2002, inaugurated an ***operational*** center for scholarship on engineering education

CASEE

CASEE Mission

Enable engineering education to meet, in a significantly better way, the needs of employers, educators, students, and society at large.

CASEE Objectives

Working collaboratively with key stakeholders, CASEE

- **Encourages rigorous research on all elements of the engineering education system, and**
- **Seeks broad dissemination, adoption, and use of research findings.**

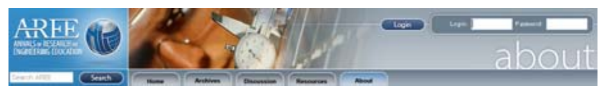
CASEE

Research Thrust Areas

1. **Define the bodies-of-knowledge required for engineering practice and use of engineering study for other careers.**
2. **Develop strategies that value diversity in the formulation and solution of engineering problems.**
3. **Develop cost-effective and time-efficient strategies and technologies for**
   - Improving student learning, and
   - Enhancing the instructional effectiveness of current and future faculty.
4. **Develop assessments of student learning and instructional effectiveness.**

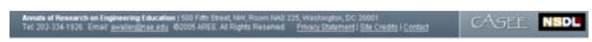
CASEE

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

www.areeonline.org

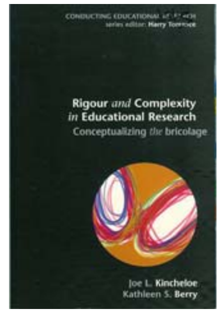
Conducting Rigorous Research in Engineering Education: Creating a Community of Practice (RREE)

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

Rigorous Research 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)

Key Aspects of Engineering Education Research



- Rigor
- Complexity – order emerges from a large number of distributed efforts, through a process of coevolution (Hagel & Seely Brown, 2005)
- Methodology – Bricolage – using the tools available to complete a task

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

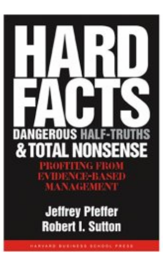
Research Inspired By:

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.

Evidence-Based Management



Pfeffer, Jeffrey & Sutton, Robert I. 2006. *Hard Facts, Dangerous Half-Truths And Total Nonsense: Profiting From Evidence-Based Management.* Cambridge, MA: Harvard Business School Press.

Short Read:
Pfeffer, Jeffrey & Sutton, Robert I. 2006. Evidence-based management. *Harvard Business Review*, January 2006.

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, Forthcoming in *Academy of Management Review,* Last revised January 24, 2005

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.