Transforming Engineering Education
based on
Educational Research and Scholarship

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SCHOOL OF
ENGINEERING EDUCATION

Inspiring Future Engineers @ Purdue

Purdue Overall
75,000 students
5000 academics

West Lafayette
32,000 UG
8,000 PG

Engineering
10,000 students

Research
$600m/pa

Neil Armstrong Hall of Engineering
A Proud History of Innovation

- 1st Department of Freshman Engineering – 1953
- 1st Women in Engineering Program – 1969
- National Society of Black Engineers (NSBE) founded at Purdue – 1975
- Engineering Projects in Community Service (EPICS), winner of 2005 NAE’s Gordon Prize – 1995
- 1st Department of Engineering Education – 2004
- 23 astronauts; first & most recent person to walk on moon.

College of Engineering

- 11 Schools
  - Aeronautical and Astronautics
  - Agricultural & Biological Engineering
  - Biomedical Engineering
  - Chemical Engineering
  - Civil Engineering
  - Electrical & Computer Engineering
  - Engineering Education
  - Industrial Engineering
  - Materials Engineering
  - Mechanical Engineering
  - Nuclear Engineering

- 3 Divisions
  - Construction Engineering Management
  - Ecological and Environmental Engineering
  - Engineering Professional Education

- 7500 undergraduates
- 2500 post-grad students
- 359 academic staff growing to 460 by 2016
Why Evidence-based Engineering Education?

When it comes to educating our future engineers, we can no longer afford “an enterprise of methodical guessing” (Bertrand Russell).

Grand questions

*What are the characteristics of engineering learning and knowing?*

*How can we best prepare engineers for roles in society?*

Kamyar Haghighi (2007)
Virtuous Cycle of Research & Practice

- Practice identifies and motivates questions that lead to ideas which result in research.
- Research helps improve answers which in turn generate insights.

Based on Booth, Colomb & Williams (2003)

Presentation Outline

- Innovation in Engineering Education
- Engineering Education Research Capacity
- Practice-Research Nexus

Transforming Engineering Education Keynote
EE 2012, Coventry, UK – Sept. 18, 2012
Innovation in Engineering Education

Adopting evidence-based practices we know work

“How People Learn” Framework

a) learners use their current knowledge to construct new knowledge

b) the ability to think and solve problems requires well-organized knowledge that is accessible in appropriate contexts

c) assessments must reflect the learning goals that define various environments

d) community of students, teachers, and other interested participants share norms that value learning and high standards

e) alignment of all four perspectives increases potential through overlap and mutual influence of one another

Dr. David F. Radcliffe, Purdue University

Pedagogies to Support Learning

- Oral
- Written
- Lecture based
- Skills based
- Technology enhanced
- Knowledge of how people learn

Individual vs. group
- Self-study
- Cooperative learning
- Jigsaw learning

Inquiry based
- Learning by design
- Projects
- Problems
- Case studies
- Modeling
- Contextualized practice
- Isolated drill and practice

Communication environments
- Electronic tools
- Assessment opportunities

Example Practice: Cooperative Learning

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

Source: Karl Smith
Research Evidence for Cooperative Learning

- Over 300 Experimental Studies
- First study conducted in 1924
- High Generalizability
- Multiple Outcomes


Innovation with Impact

ASEE Year of Dialogue
2006

Series of events
Engaged 1000’s of engineering educations and researchers

Educational Practice
identifies and motivates

Questions Ideas
which lead to

Educational Research

Answers Insights
that results in

Final Report
June 2012

creating a culture for scholarly and systematic innovation in engineering education
Recommendations

Who
- Faculty & administrators
- Grow professional development in teaching and learning.
- Expand collaborations.

What
- Expand efforts to make engineering more engaging, relevant, and welcoming (student focus)

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

Creating a Better Culture
Measures progress in implementing policies, practices, and infrastructure in support of scholarly and systematic innovation in engineering education:
- Conduct periodic self-assessments in individual institutions.
- Conduct periodic community-wide self-assessments.

Discipline-Based Education Research (DBER)

Goals of the Study
1. Synthesize empirical research on undergraduate teaching and learning in physics, chemistry, engineering, biology, the geosciences, and astronomy.
2. Examine the extent to which this research currently influences undergraduate science instruction.
3. Describe the intellectual and material resources that are required to further develop DBER.
Transforming Engineering Education Keynote
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Translating Research-to-Practice

Available evidence suggests that DBER and related research have not yet prompted widespread changes in teaching practice among science and engineering faculty.

Efforts to translate DBER and related research into practice are more likely to succeed if they:

• are consistent with research on motivating adult learners,
• include a deliberate focus on changing faculty conceptions about teaching and learning,
• recognize the cultural and organizational norms of the department and institution, and
• work to address those norms that pose barriers to change in teaching practice.

Empirical Evidence for Successful Reform

A two stage study of major engineering education reform across the world with the aim of distilling the common features of success and failure.

Phase 1: Interviews with 70 international experts from 15 countries, each with first-hand experience of curriculum change in Engineering – features of success and failure

Phase 2: Six case studies of highly regarded reform efforts to provide a spectrum of drivers for reform, change strategies, levels of ambition, geographical locations and stages in the change process. (117 individuals consulted for these case studies).

Conducted Jan-Oct 2011

Recommendations for Success

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<tr>
<th>PREPARE</th>
<th>Collect Evidence</th>
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<td></td>
<td>Engage the Department Head</td>
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<td>Consult senior university management</td>
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<th>PLAN</th>
<th>Communicate need for reform to all faculty</th>
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<td>Faculty-wide curriculum design</td>
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<td>Consult external perspectives</td>
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<td>Appoint a management team and release their time</td>
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<td>Establish impact evaluation</td>
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<th>IMPLEMENT</th>
<th>Select implementers of reform</th>
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<td></td>
<td>Loosen direct link between faculty &amp; individual courses</td>
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<td>Maintain momentum</td>
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<th>SUSTAIN</th>
<th>Closely monitor impact data</th>
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<td>Make new faculty aware of the reform</td>
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<td>Establish an on-going focus on education</td>
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<td>Be aware of potential issues</td>
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Practice-Research Nexus

*Examples of research at Purdue informing practice*
How Can We Improve Learning Outcomes?

Over 2000 first-year engineering students

Ideas-to-Innovation (i2i) Learning Lab

“...after that our buildings shape us”
Sir Winston Churchill

Transforming Engineering Education

Keynote EE 2012, Coventry, UK – Sept. 18, 2012
Enabling Active and Collaborative Learning

2000 students/semester
7:30am - 5:30pm
5 days/week

increased retention rates

Model-Eliciting Activities (MEAs)

Models and Modeling in Engineering Education
Designing Experiences for All Students

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Keynote EE 2012, Coventry, UK – Sept. 18, 2012
Success & Retention

References:

Race, Gender, and Measures of Success in Engineering Education
MATTHEW W. ORLANDO, CATHERINE E. BRAYNEY, MICHELLE M. CAMACHO, BRIANA A. LAYTON, RHEEJAA L. LEE, SIZHAN M. LIU, AND MARA H. WASSER
Purdue University, Research Triangle Educational Consultant, University of San Diego, Research Triangle Institute of Technology

BACKGROUND
Currents for workforce needs, social justice, and the diversification of the engineering workforce are driving increased focus on understanding the drivers of retention and success in engineering.

METHODS
White males are assigned to study rooms, and participants are measured after each study session.

CONCLUSIONS
The study concludes that males and females have different retention and success rates in engineering programs.

Decision Making in Teams

Reference:

Engineering Learning Observatory

https://engineering.purdue.edu/MIDFIELD/p1.htm
Global Engineering Competencies

LOCAL CONTEXTS OF PRACTICE
- Engineering Teaching
- Engineering Profession
- Policy

LOCAL CONTEXTS OF ENGINEERING EDUCATION RESEARCH
- National/Regional
- Disciplinary

GLOBAL CORE
- Research Areas
- Bodies of Knowledge
- Theories
- Methods

Critical / Feminist Perspectives

ENGINEERING AND SOCIAL JUSTICE
In the University and Beyond

edited by Caroline Bilble, Alice Pawley, and Donna Riley
Purdue University Press
Institute for P-12 Engineering Learning & Research

• **Mission:** To study engineering thought and learning at the P-12 level and to inspire diverse students to pursue engineering and science for the benefit of humanity and the advancement of society.

• **Research:** Basic and applied multidisciplinary research focusing on—teacher professional development, assessment, student learning, and informal learning.

• **People:**
  - 9 academic staff
  - 5 postdoctoral fellows
  - 15 graduate students
  - 20 undergraduate researchers
  - 3 support staff

INSPIRE Research and Example Projects

➢ **Student Learning Research**
  - Model-eliciting activities to foster scientific, mathematical and technological literacy

➢ **Teacher Research**
  - Teachers conceptual understanding of engineering
  - Cyber-enabled Teacher Professional Development to increase Knowledge-Attitudes-Behavior
  - Desired teachers’ engineering (and teaching) competencies

➢ **Assessment research**
  - Teaching self-efficacy Instrument

➢ **Informal Learning Research**
  - Parents’ Engineering Awareness Survey (PEAS)
  - Pre-school children’s play as an engineering activity
Building Research Capacity

Having a critical mass of change agents

A New Department with Deep Roots

April 9, 2004

1953 Freshman Engineering (Common First Year)

1969 Interdisciplinary Engineering Degree

1953 Research and Scholarship of Engineering Education

1955 School of Engineering Education

1969 BS in Multidisciplinary Engineering & IDES

2005 Graduate Program in Engineering Education
Our Vision for Engineering Education

**A more inclusive, socially connected and scholarly engineering education**

We envision engineers who, in collaboration with others, help communities globally to achieve their aspirations in creative yet responsible and sustainable ways. Their education is informed by sophisticated knowledge about how people learn to engineer, one that attracts and develops a diverse range of people and is suited to addressing complex socio-technical issues. This implies we radically re-think the boundaries of engineering and the purpose of engineering education.

ENE Strategic Plan (2009-14)

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Mission of School of Engineering Education

**Transforming engineering education based on scholarship and research**

- Re-imagine Engineering and Engineering Education
  - Diversify engineering
  - Embed creativity, innovation & social responsibility
  - Enrich the student experience
- Create field-shaping Knowledge
- Empower Agents of Change

ENE Strategic Plan (2009-14)
Scope of Engineering Education (Research)

learning *about*, learning *to* and learning *improved practices* in relation to *engineering*;
across all life and career stages
*in formal and informal learning environments*
*by constructing knowledge and meaning and forming identities as a member of a community*

An Emergent Body of Educational Research

[Link](https://engineering.purdue.edu/ENE/Research/ResearchReport)
PhD Program in Engineering Education

- Commencing
- Current
- Graduates

- 72 Current PhD Students
- 23 PhD Graduates

ENE PhD Competencies

- Create Knowledge
- Synthesize Knowledge
- Communicate Knowledge
- Think Critically and Reflectively
- Apply Engineering Education Principles to the Solution of Instructional or Curricular Problems
- Teach Engineering
- Demonstrate Engineering Skills
- Participate Actively in Professional Community
- Engage in Professional Development
- Explain and Critique Education Policy

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Current and Future Careers

Policy

Professional societies

Learning to make a difference

NGOs

Industry

Universities

P-12 & Community

Change: A New Way of Being

What is your theory of change?
Recommendations for Educational Reform

- Engage academics and administrators
- Prepare, Plan, Implement, Sustain
- Recognize the cultural and organizational norms
- Raise awareness of proven practices and of scholarship in engineering education
- Build off external change drivers
- Establish impact metrics and evaluate
- Work to address those norms that pose barriers to change in teaching practice

Theory of Change

A theory of change is a predictive assumption about the relationship between desired changes and the actions that may produce those changes. Putting it another way, “If I do x, then I expect y to occur, and for these reasons.”

Mark Connolly and Elaine Seymour (2009)
Changing the Culture: Challenging Core Beliefs

- Artifacts
- Processes
- Vision & Strategy

Visible

Partially Visible

Invisible

What we say we do but not necessarily what we do

How we actually behave

Basis of the work culture we build

Symbols & Stories
- Customs / Norms
- Shared and Unshared Assumptions
- Unwritten Rules and Attitudes
- Core Values & Beliefs

Beware: *Culture Eats Strategy for Breakfast*

Peter Drucker
When Do People Change?

“.....learning, and more generally change, occurs when the ‘survival anxiety’ of an individual or group exceeds their ‘learning anxiety’.....”


Survival anxiety

Learning anxiety

The levers we can operate

The Virtuous Learning / Change Cycle

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Resources

School of Engineering Education (ENE) at Purdue
https://engineering.purdue.edu/ENE

ENE Research Report
https://engineering.purdue.edu/ENE

ENE Strategic Plan
https://engineering.purdue.edu/ENE/AboutUs/StratPlan.pdf

AAEE: Innovation with Impact

Disciple-based Educational Research
http://www.nap.edu/catalog.php?record_id=13362

RAE/MIT: Achieving Excellence in Engineering Education