Levels of Education Inquiry

- **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** Scholarship 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 on Designing Courses based on *How People Learn* and *Understanding by Design*

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National Academy of Engineering
Frontiers of Engineering Education
November 2011

Session Layout

- Welcome & Overview
- Course Design Foundations
  - How People Learn (HPL)
    - How Learning Works (Ambrose, et al.)
  - Understanding by Design (UdB)
    - Integrated Course Design (CAP Model)
      - Content – Assessment – Pedagogy
- Transforming Engineering Education
  - Engineering Education Innovation
  - Linking Theory, Research Evidence and Practice
- Design and Implementation

3

Workshop Objectives

- Participants will be able to
  - Articulate an integrated approach to course design, which aligns content, assessment and pedagogy
  - Describe the research-based features of HPL & UbD
  - Apply principles to Transforming Engineering Education.
  - Use reflection and discussion to deepen your learning.

4

What do you already know about course design?

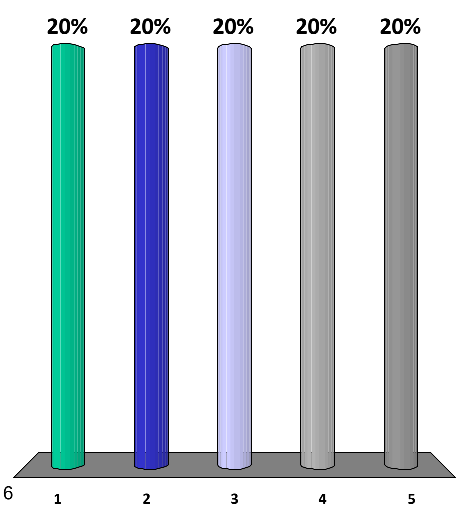
[Background Knowledge Survey]

Clicker Questions

- What is your experience with course (re) design?
  - 1-3: never done it (1) to very experienced (5)
- What is your level of familiarity with HPL & UbD?
  - 1-3: low (1) to high (5)

What is experience with course design?

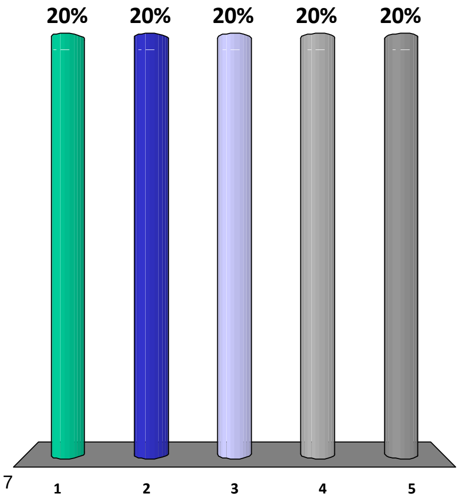
1. Little
2. Between 1&2
3. Moderate
4. Between 3&4
5. Extensive



6

What is your level familiarity with HPL & UbD?

1. Low
2. Between 1&2
3. Moderate
4. Between 3&4
5. High



7

What do you already know about course design?

[Background Knowledge Survey]

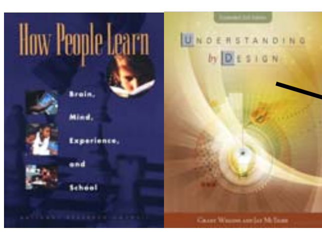
Short Answer Questions

- What do you feel are important considerations about course (re) design?
- What are challenges you have faced with course (re) design?

"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*."

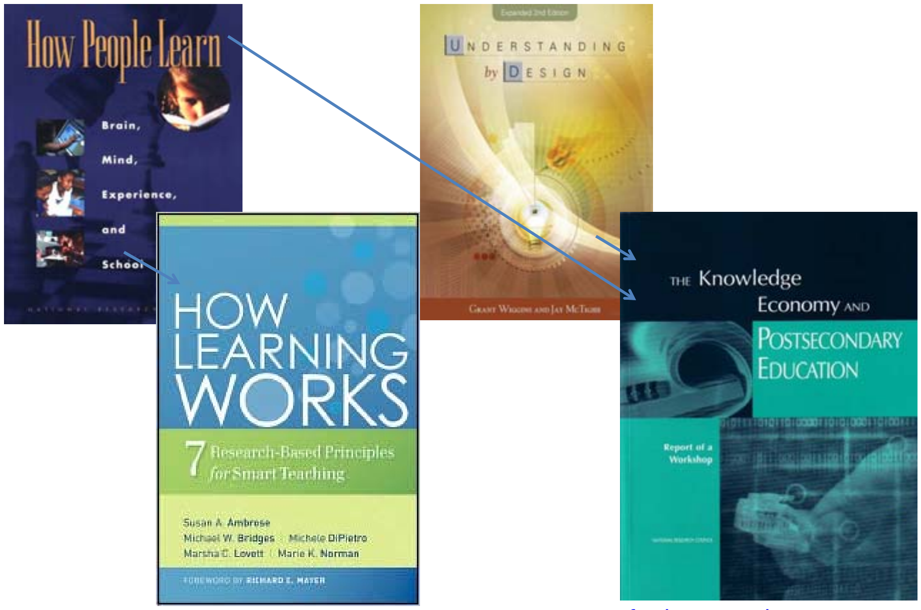
James Duderstadt, 1999
Nuclear Engineering Professor; Dean, Provost and President of the University of Michigan

Design Foundations

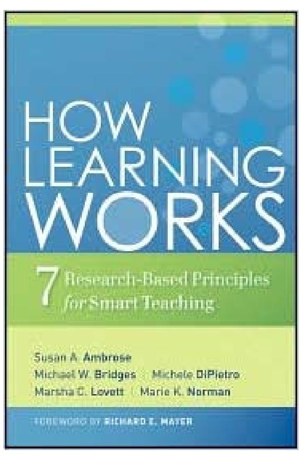


		Science of Instruction (UbD)	
		No	**Yes**
Science of Learning (HPL)	**Yes**	Good Theory/ Poor Practice	Good Theory & Good Practice
	No		Good Practice/ Poor Theory

Sources: Bransford, Brown & Cocking. 1999. *How people learn.* National Academy Press.
Wiggins, G. & McTighe, J. 2005. *Understanding by design, 2ed*. ASCD.



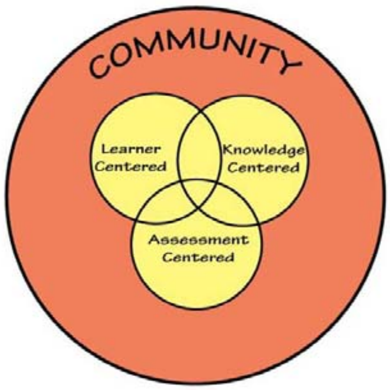
•Bransford, Vye and Bateman – Creating High Quality Learning Environments



1. Students prior knowledge can help or hinder learning
2. How student organize knowledge influences how they learn and apply what they know
3. Students' motivation determines, directs, and sustains what they do to learn
4. To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned
5. Goal-directed practice coupled with targeted feedback enhances the quality of students' learning
6. Students' current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning
7. To become self-directed learners, students must learn to monitor and adjust their approach to learning

How People Learn (HPL)

HPL Framework



- Expertise Implies (Ch. 2):
  - 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.

Understanding by Design

Wiggins & McTighe (1997, 2005)

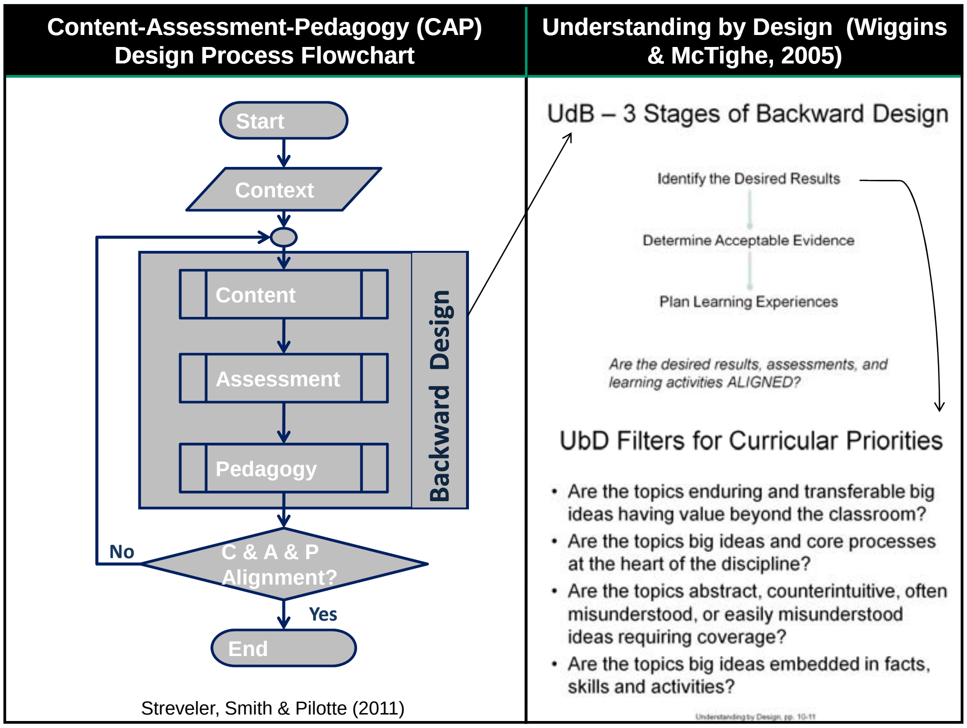
Stage 1. Identify Desired Results

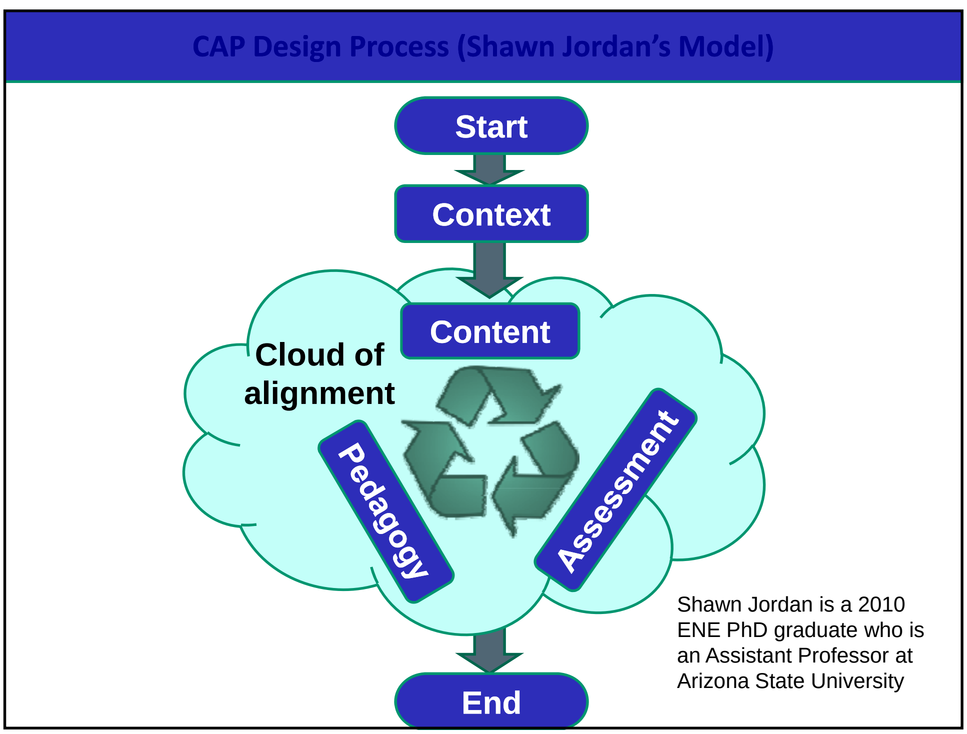
Stage 2. Determine Acceptable Evidence

Stage 3. Plan Learning Experiences and Instruction

Overall: *Are the desired results, assessments, and learning activities ALIGNED?*

From: Wiggins, Grant and McTighe, Jay. 1997. *Understanding by Design*. Alexandria, VA: ASCD


Content-Assessment-Pedagogy (CAP) Design Process Flowchart
Understanding by Design (Wiggins & McTighe, 2005)
Start
Context
Content
Assessment
Pedagogy
Backward Design
No
C & A & P Alignment?
Yes
End
Streveler, Smith & Pilotte (2011)
UdB – 3 Stages of Backward Design
Identify the Desired Results
Determine Acceptable Evidence
Plan Learning Experiences
Are the desired results, assessments, and learning activities ALIGNED?
UbD Filters for Curricular Priorities
• Are the topics enduring and transferable big ideas having value beyond the classroom?
• Are the topics big ideas and core processes at the heart of the discipline?
• Are the topics abstract, counterintuitive, often misunderstood, or easily misunderstood ideas requiring coverage?
• Are the topics big ideas embedded in facts, skills and activities?


CAP Design Process (Shawn Jordan's Model)
Start
Context
Content
Cloud of alignment
Pedagogy
Assessment
End
Shawn Jordan is a 2010 ENE PhD graduate who is an Assistant Professor at Arizona State University

3 Stages of Understanding by Design

Identify the Desired Results

What should students know, understand, and be able to do?

Three categories of learning outcomes:
(1) **Enduring understandings**
(2) Important to know
(3) Good to be familiar with

3 Stages of Understanding by Design

Identify the Desired Results

↓

Determine Acceptable Evidence

How will we know if the students have achieved the desired results? What will be accepted as evidence of student understanding and proficiency?

Taxonomies of Types of Learning

Bloom's taxonomy of educational objectives: Cognitive Domain (Bloom & Krathwohl, 1956)

A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives (Anderson & Krathwohl, 2001).

Facets of understanding (Wiggins & McTighe, 1998)

Taxonomy of significant learning (Fink, 2003)

Evaluating the quality of learning: The SOLO taxonomy (Biggs & Collis, 1982)

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The Six Major Levels of Bloom's Taxonomy of the Cognitive Domain (with representative behaviors and sample objectives)

Knowledge. Remembering information *Define, identify, label, state, list, match*

- Identify the standard peripheral components of a computer
- Write the equation for the Ideal Gas Law

Comprehension. Explaining the meaning of information *Describe, generalize, paraphrase, summarize, estimate*

- In one sentence explain the main idea of a written passage
- Describe in prose what is shown in graph form

Application. Using abstractions in concrete situations *Determine, chart, implement, prepare, solve, use, develop*

- Using principles of operant conditioning, train a rate to press a bar
- Derive a kinetic model from experimental data

Analysis. Breaking down a whole into component parts *Points out, differentiate, distinguish, discriminate, compare*

- Identify supporting evidence to support the interpretation of a literary passage
- Analyze an oscillator circuit and determine the frequency of oscillation

Synthesis. Putting parts together to form a new and integrated whole *Create, design, plan, organize, generate, write*

- Write a logically organized essay in favor of euthanasia
- Develop an individualized nutrition program for a diabetic patient

Evaluation. Making judgments about the merits of ideas, materials, or phenomena *Appraise, critique, judge, weigh, evaluate, select*

- Assess the appropriateness of an author's conclusions based on the evidence given
- Select the best proposal for a proposed water treatment plant

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The Cognitive Process Dimension

The Knowledge Dimension

	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge – The basic elements that students must know to be acquainted with a discipline or solve problems in it. a. Knowledge of terminology b. Knowledge of specific details and elements						
Conceptual Knowledge – The interrelationships among the basic elements within a larger structure that enable them to function together. a. Knowledge of classifications and categories b. Knowledge of principles and generalizations c. Knowledge of theories, models, and structures						
Procedural Knowledge – How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. a. Knowledge of subject-specific skills and algorithms b. Knowledge of subject-specific techniques and methods c. Knowledge of criteria for determining when to use appropriate procedures						
Metacognitive Knowledge – Knowledge of cognition in general as well as awareness and knowledge of one's own cognition. a. Strategic knowledge b. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge c. Self-knowledge						

(Anderson & Krathwohl, 2001).

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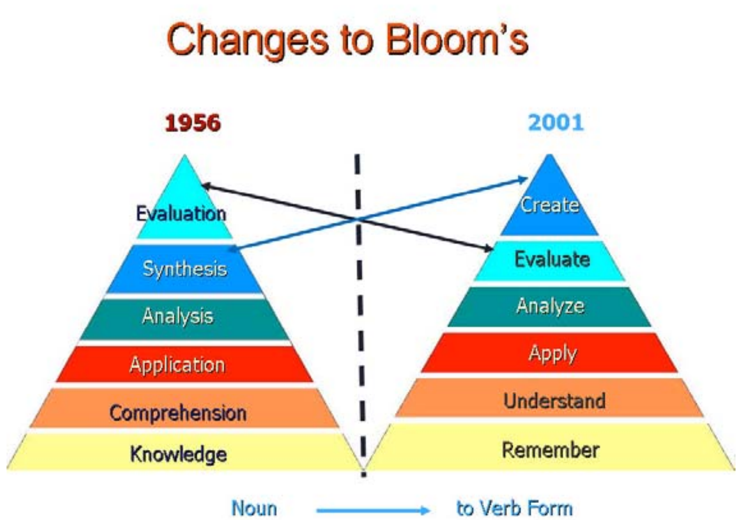

http://www.uwsp.edu/education/lwilson/curric/newtaxonomy.htm

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Dee Fink – Creating Significant Learning Experiences

A TAXONOMY OF SIGNIFICANT LEARNING

Cognitive

1. Foundational Knowledge

- "Understand and remember" learning

  For example: facts, terms, formulae, concepts, principles, etc.

2. Application

- Thinking: critical, creative, practical (problem-solving, decision-making)
- Other skills

  For example: communication, technology, foreign language

- Managing complex projects

3. Integration

- Making "connections" (i.e., finding similarities or interactions) . . .

  Among: ideas, subjects, people

Affective

4. Human Dimensions

- Learning about and changing one's SELF
- Understanding and interacting with OTHERS

5. Caring

- Identifying/changing one's feelings, interests, values

Meta

6. Learning How to Learn

- Becoming a better student
- Learning how to ask and answer questions
- Becoming a self-directed learner

3 Stages of Understanding by Design

Identify the Desired Results

↓

Determine Acceptable Evidence

↓

Plan Learning Experiences

*What **activities** will equip students with the needed knowledge and skills?*

*What **materials** and resources will be useful?*

*Are the desired results, assessments, and learning activities **ALIGNED**?*

Emphasis on Innovation

- NSF TUES (CCLI) PI Meeting – Transforming Undergraduate Education in STEM
  - Myles Boylan presentation
  - Carl Wieman presentation – White House – Office of Science and Technology Policy
  - http://ccliconference.org/meetings/2011-tues-conference/
- ASEE Annual Conference – Main Plenary – 2011
  - http://www.asee.org/conferences-and-events/conferences/annual-conference/2011/program-schedule/conference-highlights
- NAE Frontiers of Engineering Education (FOEE)
  - http://www.nae.edu/Activities/Projects20676/CASEE/26338/35816/FOEE.aspx

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The Federal Environment for STEM Education Programs: Implications for TUES

& Some of your suggestions

Myles Boylan
Division of Undergraduate Education
National Science Foundation
CCLI PI Meeting January 28, 2011

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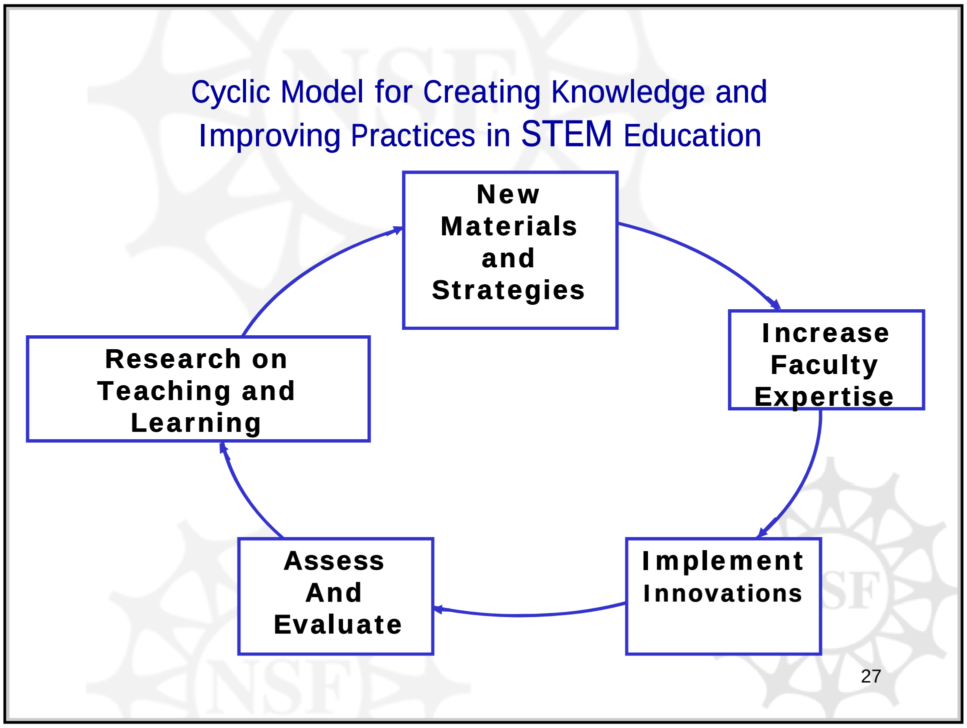
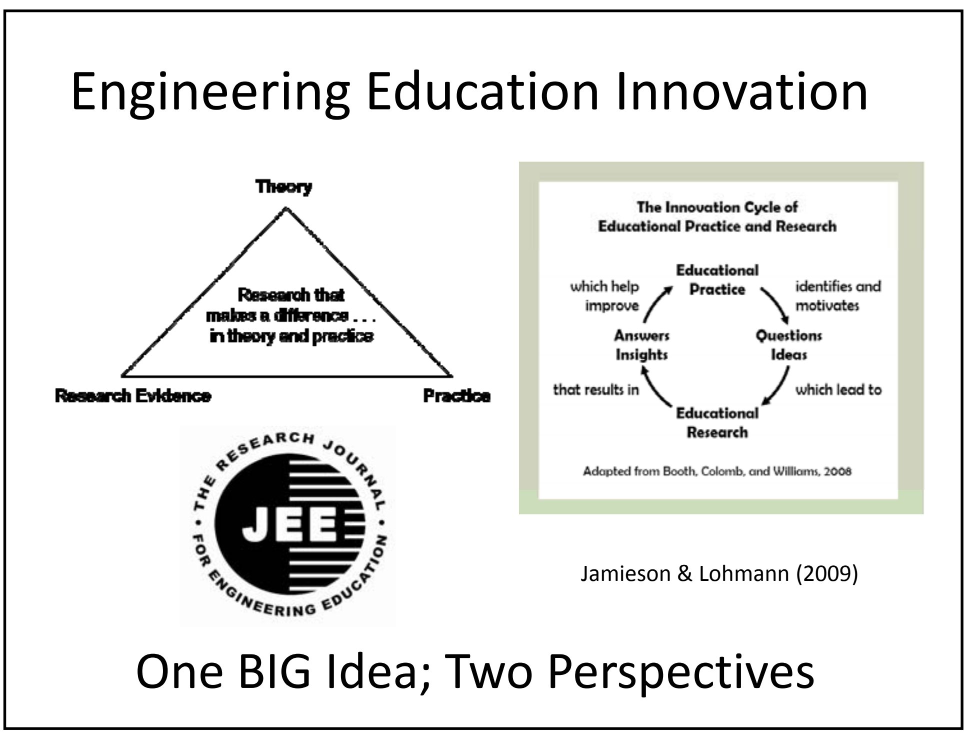
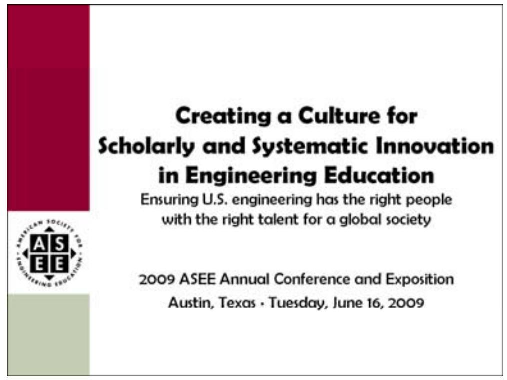

Cyclic Model for Creating Knowledge and Improving Practices in STEM Education
New Materials and Strategies
Increase Faculty Expertise
Implement Innovations
Assess And Evaluate
Research on Teaching and Learning
27


Engineering Education Innovation
Theory
Research that makes a difference . . . in theory and practice
Research Evidence
Practice
THE RESEARCH JOURNAL FOR ENGINEERING EDUCATION
JEE
The Innovation Cycle of Educational Practice and Research
Educational Practice
identifies and motivates
Questions Ideas
which lead to
Educational Research
that results in
Answers Insights
which help improve
Adapted from Booth, Colomb, and Williams, 2008
Jamieson & Lohmann (2009)
One BIG Idea; Two Perspectives

Celebration of Two Major ASEE Milestones



2011 ASEE Annual Conference and Exposition

Vancouver, British Columbia • Monday, June 27, 2011

ASEE Main Plenary, 8:45 a.m. – 10:15 a.m.
Vancouver International Conference Centre, West Ballroom CD
Expected to draw over 2,000 attendees, this year's plenary features Karl A. Smith, Cooperative Learning Professor of Engineering Education at Purdue University and Morse–Alumni Distinguished Teaching Professor & Professor of Civil Engineering at the University of Minnesota.

Smith has been at the University of Minnesota since 1972 and has been active in ASEE since he became a member in 1973. For the past five years, he has been helping start the engineering education Ph.D. program at Purdue University. He is a Fellow of the American Society for Engineering Education and past Chair of the Educational Research and Methods Division. He has worked with thousands of faculty all over the world on pedagogies of engagement, especially cooperative learning, problem-based learning, and constructive controversy.

On the occasion of the 100th anniversary of the Journal of Engineering Education and the release of ASEE's Phase II report *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education* (Jamieson/Lohmann report), the plenary will celebrate these milestones and demonstrate rich, mutual interdependences between practice and inquiry into teaching and learning in engineering education. Depth and range of the plenary will energize the audience and reflects expertise and interests of conference participants. One of ASEE's premier educators and researchers, Smith will draw upon our roots in scholarship to set the stage and weave the transitions for six highlighted topics selected for their broad appeal across established, evolving, and emerging practices in engineering education.

Highlights from Monday:

Monday's **Main Plenary** by Karl A. Smith, Cooperative Learning Professor of Engineering Education at Purdue University and Morse-Alumni Distinguished Teaching Professor & Professor of Civil Engineering at the University of Minnesota, focused on six highlighted topics (presented by six different educators) selected for their broad appeal across established, evolving, and emerging practices in engineering education.

Video: https://secure.vimeo.com/27147996
Slides: http://www.ce.umn.edu/~smith/links.html
http://www.asee.org/conferences-and-events/conferences/annual-conference/2011/program-schedule/conference-highlights

Engineering Education Innovation
Karl Smith

Research
•Process Metallurgy 1970 -1992
•Learning ~1974
•Design ~1995
•Engineering Education Research & Innovation ~ 2000

Innovation – Cooperative Learning
•Need identified ~1974
•Introduced ~1976
•FIE conference 1981
•*JEE* paper 1981
•Research book 1991
•Practice handbook 1991
•*Change* paper 1998
•*Teamwork and project management* 2000
•*JEE* paper 2005

National Academy of Engineering - Frontiers of Engineering Education Symposium - December 13-16, 2010 - Slides PDF [Smith-NAE-FOEE-HPL-UbD-12-10-v8.pdf]

Process Metallurgy

- Dissolution Kinetics – liquid-solid interface
- Iron Ore Desliming – solid-solid interface
- Metal-oxide reduction roasting – gas-solid interface

Dissolution Kinetics

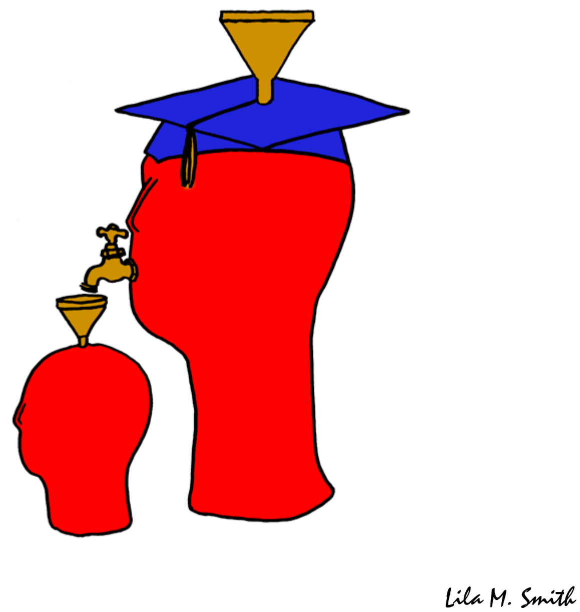
- Theory – Governing Equation for Mass Transport
- Research – rotating disk
- Practice – leaching of silver bearing metallic copper

$$(\nabla c \bullet \underline{v}) = D\nabla^2 c$$

$$v_y \frac{dc}{dy} = D\frac{d^2c}{dy^2}$$

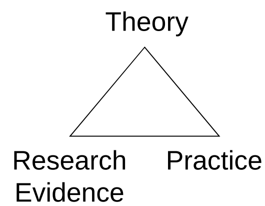
First Teaching Experience

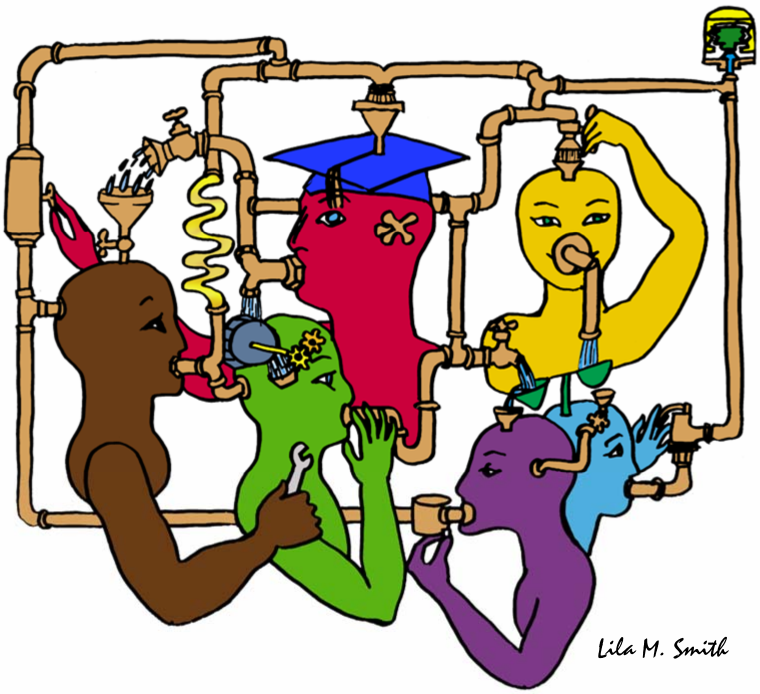
- Practice – Third-year course in metallurgical reactions – thermodynamics and kinetics



Engineering Education

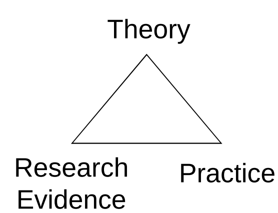
- Practice – Third-year course in metallurgical reactions – thermodynamics and kinetics
- Research – ?
- Theory – ?





Cooperative Learning

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



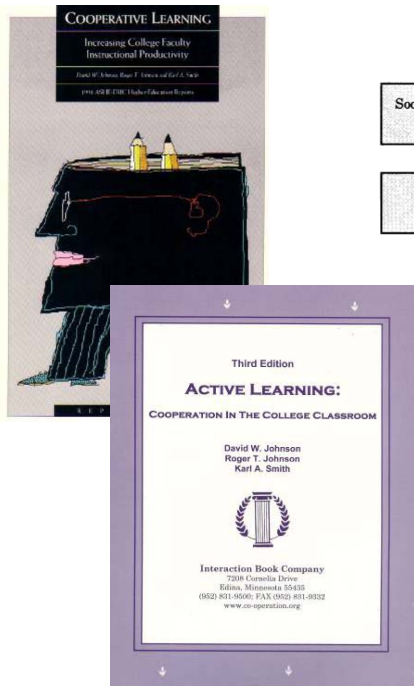
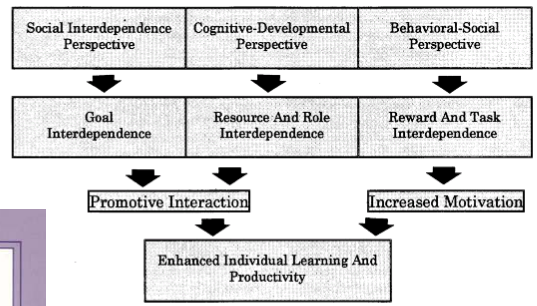


Figure A.1 A General Theoretical Framework



Cooperative Learning

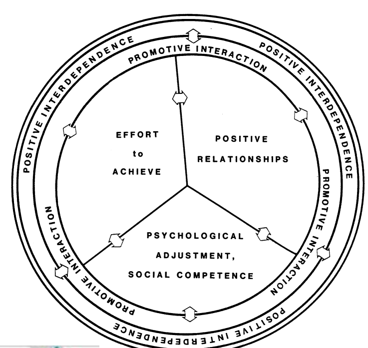
- Positive Interdependence
- Individual and Group Accountability
- Face-to-Face Promotive Interaction
- Teamwork Skills
- Group Processing

[*First edition 1991]

Cooperative Learning Research Support

Johnson, D.W., Johnson, R.T., & Smith, K.A. 1998. Cooperative learning returns to college: What evidence is there that it works? *Change*, *30* (4), 26-35.

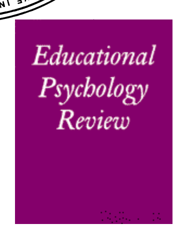
- Over 300 Experimental Studies
- First study conducted in 1924
- High Generalizability
- Multiple Outcomes



Outcomes

1. Achievement and retention
2. Critical thinking and higher-level reasoning
3. Differentiated views of others
4. Accurate understanding of others' perspectives
5. Liking for classmates and teacher
6. Liking for subject areas
7. Teamwork skills

January 2005



March 2007

Cooperative Learning is instruction that involves people working in teams to accomplish a common goal, under conditions that involve both *positive interdependence* (all members must cooperate to complete the task) and *individual and group accountability* (each member is accountable for the complete final outcome).

Key Concepts

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

http://www.ce.umn.edu/~smith/docs/Smith-CL%20Handout%2008.pdf

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

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JEE December 1981

Cooperative Learning Adopted

The American College Teacher:

National Norms for 2007-2008

Methods Used in “All” or “Most”	All – 2005	All – 2008	Assistant - 2008
Cooperative Learning	48	59	66
Group Projects	33	36	61
Grading on a curve	19	17	14
Term/research papers	35	44	47

http://www.heri.ucla.edu/index.php

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Designing and Implementing Cooperative Learning

- Think like a designer
- Ground practice in robust theoretical framework
- Start small, start early and iterate
- Celebrate the successes; problem-solve the failures

Pedagogies of Engagement

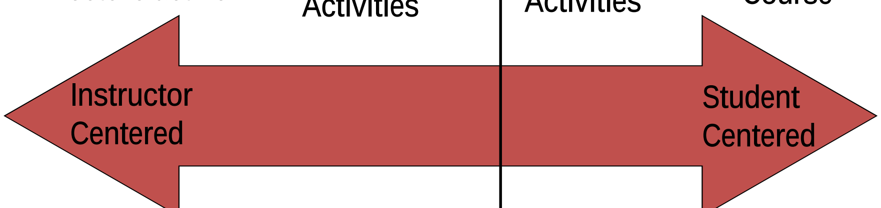
The Active Learning Continuum

Make the lecture active

Informal Group Activities

Structured Team Activities

Problems Drive the Course



Active Learning

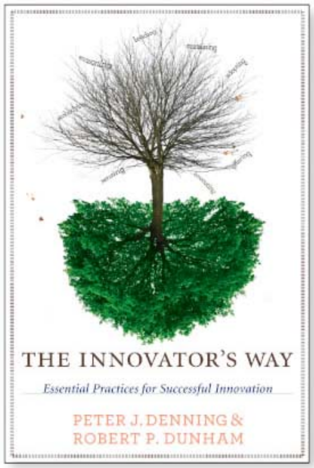
Collaborative Learning

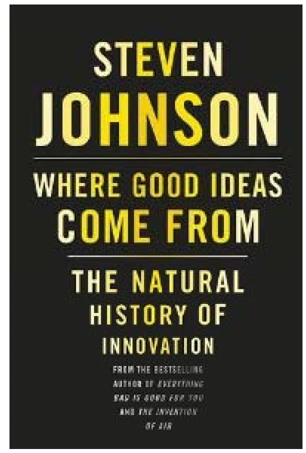
Cooperative Learning

Problem-Based Learning

Prince, M. (2010). NAE FOEE

My work is situated here – Cooperative Learning & Challenge-Based Learning





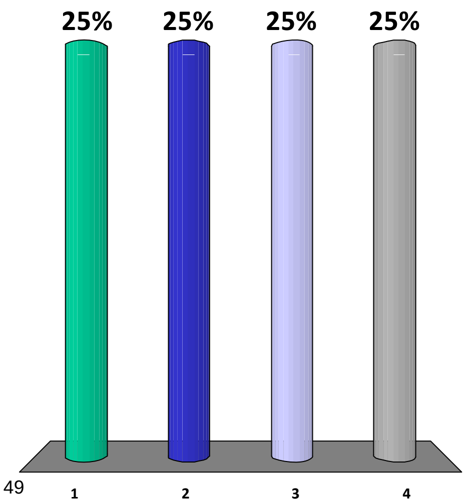
Innovation is the adoption
of a new practice in a community
- Denning & Dunham (2010)

*Education Innovation

- Stories supported by evidence are essential for adoption of new practices
  - Good ideas and/or insightful connections
  - Supported by evidence
  - Spread the word
  - Patience and persistence
- Cooperative learning took over 25 years to become widely practiced in higher education
- **We can't wait 25 years for YOUR innovations to become widely practiced!**

Extent to which your Innovation Student Learning Outcomes are Aligned with Assessment and Instruction?

1. Low
2. Somewhat
3. Moderate
4. High



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Reflection and Dialogue

- Individually reflect on your Education Innovation. Write for about 1 minute
  - Are the student learning outcomes clearly articulated?
    - Are they BIG ideas at the heart of the discipline?
  - Are the assessments aligned with the outcomes?
  - Is the pedagogy aligned with the outcomes & assessment?
- Discuss with your neighbor for about 2 minutes
  - Select Design Example, Comment, Insight, etc. that you would like to present to the whole group if you are randomly selected

Resources

- Design Framework – How People Learn (HPL) & Understanding by Design (UdB) Process
  - Bransford, John, Vye, Nancy, and Bateman, Helen. 2002. Creating High-Quality Learning Environments: Guidelines from Research on How People Learn. *The Knowledge Economy and Postsecondary Education: Report of a Workshop*. National Research Council. Committee on the Impact of the Changing Economy of the Education System. P.A. Graham and N.G. Stacey (Eds.). Center for Education. Washington, DC: National Academy Press. http://www.nap.edu/openbook/0309082927/html/
  - Mayer, R. E. 2010. *Applying the science of learning.* Upper Saddle River, NJ: Pearson.
  - Pellegrino – Rethinking and redesigning curriculum, instruction and assessment: What contemporary research and theory suggests. http://www.skillscommission.org/commissioned.htm
  - Smith, K. A., Douglas, T. C., & Cox, M. 2009. Supportive teaching and learning strategies in STEM education. In R. Baldwin, (Ed.). Improving the climate for undergraduate teaching in STEM fields. New Directions for Teaching and Learning, 117, 19-32. San Francisco: Jossey-Bass.
  - Streveler, R.A., Smith, K.A. and Pilotte, M. 2011. *Aligning Course Content, Assessment, and Delivery: Creating a Context for Outcome-Based Education – http://www.ce.umn.edu/~smith/links.html*
  - Wiggins, G. & McTighe, J. 2005. *Understanding by Design: Expanded Second Edition*. Prentice Hall.
- Content Resources
  - Donald, Janet. 2002. Learning to think: Disciplinary perspectives. San Francisco: Jossey-Bass.
  - Middendorf, Joan and Pace, David. 2004. Decoding the Disciplines: A Model for Helping Students Learn Disciplinary Ways of Thinking. New Directions for Teaching and Learning, 98.
- Cooperative Learning
  - Cooperative Learning (Johnson, Johnson & Smith) - Smith web site – www.ce.umn.edu/~smith
  - Smith (2010) Social nature of learning: From small groups to learning communities. New Directions for Teaching and Learning, 2010, 123, 11-22 [NDTL-123-2-Smith-Social_Basis_of_Learning-.pdf]
  - Smith, Sheppard, Johnson & Johnson (2005) Pedagogies of Engagement [Smith-Pedagogies_of_Engagement.pdf]
  - Johnson, Johnson & Smith. 1998. Cooperative learning returns to college: What evidence is there that it works? Change, 1998, 30 (4), 26-35. [CLReturnstoCollege.pdf]
- Other Resources
  - University of Delaware PBL web site – www.udel.edu/pbl
  - PKAL – Pedagogies of Engagement – http://www.pkal.org/activities/PedagogiesOfEngagementSummit.cfm
  - Fairweather (2008) Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education - http://www7.nationalacademies.org/bose/Fairweather_CommissionedPaper.pdf

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Thank you!

An e-copy of this presentation is posted to:
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