

Evidence-Based Practices for Innovative Education

Karl A. Smith

Engineering Education – Purdue University
STEM Education Center/Civil Eng – University of Minnesota
ksmith@umn.edu - <http://www.ce.umn.edu/~smith/>

Frontiers of Engineering Education –
Educational Innovation Seminar Series
(FOEE–EISS)

Worcester Polytechnic Institute

September 7, 2011

Reflection and Dialogue

- Individually reflect on your mental image of an innovative teacher. Write for about 1 minute.
 - Jot down words or phrases
 - Construct a figure or diagram
- Discuss with your neighbor for about 2 minutes
 - Describe your mental image and talk about similarities and differences
 - Select one Element, Image, Comment, Story, etc. that you would like to present to the whole group if you are randomly selected
- Whole group discussion

Teacher Mental Images About Teaching - Axelrod (1973)

Mental Image	Motto	Characteristics	Disciplines
Content	I teach what I know	Pour it in, Lecture	Science, Math
Instructor	I teach what I am	Modeling, Demonstration	Many
Student – Cognitive Development	I train minds	Active Learning, Discussion	English, Humanities
Student – Development of Whole Person	I work with students as people	Motivation, Self-esteem	Basic Skills Teachers

Axelrod, J. *The University Teacher as Artist*. San Francisco: Jossey-Bass, 1973.

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Lila M. Smith

Engineering Education: Advancing the Practice 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

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

- Research – rotating disk

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

- Practice – leaching of silver bearing metallic copper

Iron Ore Desliming

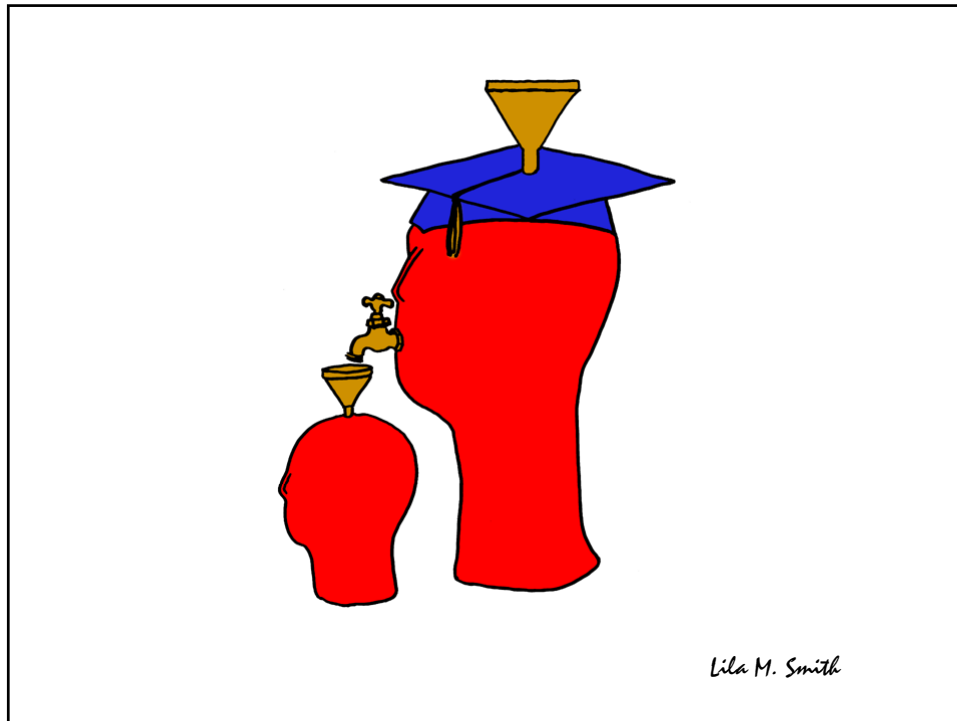
- Theory – DLVO [$V(h) = V_A(h) + V_R(h)$]
- Research – streaming potential
- Practice – recovery of iron from low-grade Fe_2O_3 ores (Selective removal of silicates)

Metal Oxide Reduction Roasting

- Theory – catalyzed gas-solid reactions
Boudouard Reaction $[\text{CO}_2 + \text{C} = 2\text{CO}]$
- Research method – thermogravimetric analysis
- Practice – extraction of Ti from FeTiO_3 ,
Al from Al_2O_3 – bearing minerals

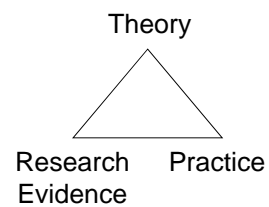
First Teaching Experience

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



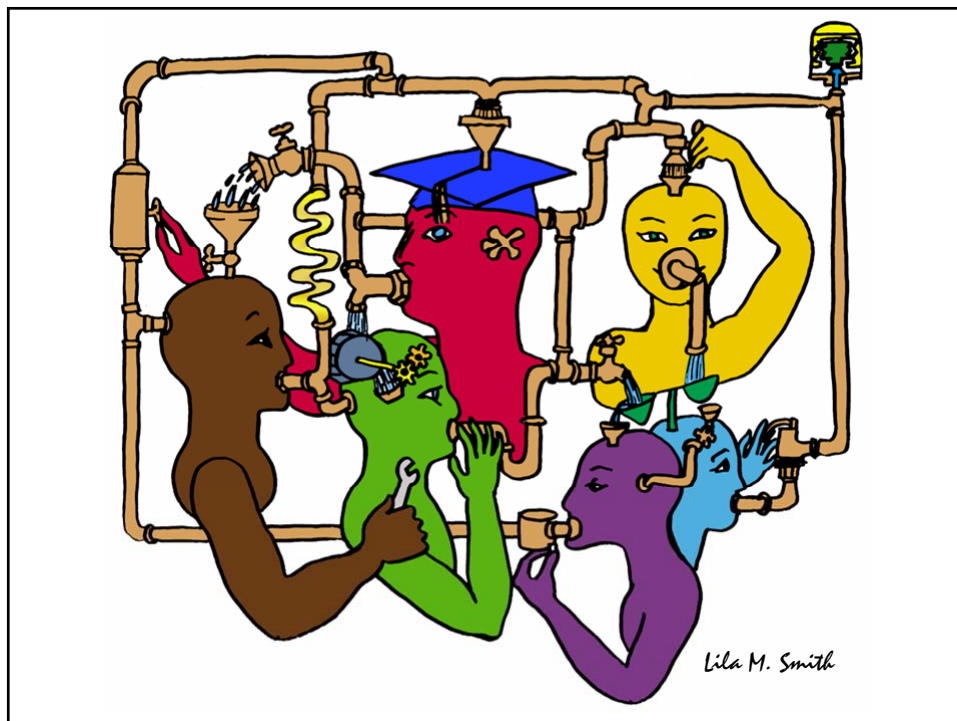
Engineering Education

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



University of Minnesota College of Education
Social, Psychological and Philosophical
Foundations of Education

- Statistics, Measurement, Research Methodology
- Assessment and Evaluation
- Learning and Cognitive Psychology
- Knowledge Acquisition, Artificial Intelligence, Expert Systems
- Social psychology of learning – student – student interaction



Pedago-pathologies

Amnesia

Fantasia

Inertia



Lee Shulman – MSU Med School – PBL Approach (late 60s – early 70s), President Emeritus of the Carnegie Foundation for the Advancement of College Teaching

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

What do we do about these pathologies?

- **Activity** – Engage learners in meaningful and purposeful activities
- **Reflection** – Provide opportunities
- **Collaboration** – Design interaction
- **Passion** – Connect with things learners care about

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

Seven Principles for Good Practice in Undergraduate Education

- Good practice in undergraduate education:
 - Encourages student-faculty contact
 - Encourages cooperation among students
 - Encourages active learning
 - Gives prompt feedback
 - Emphasizes time on task
 - Communicates high expectations
 - Respects diverse talents and ways of learning

Chickering & Gamson, June, 1987¹⁷

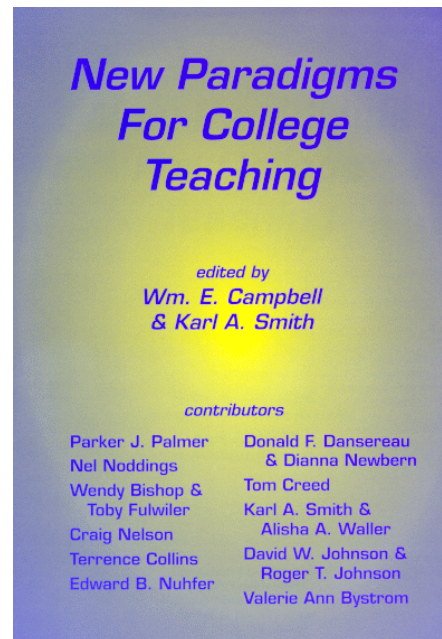
Student Engagement Research Evidence

- Perhaps the strongest conclusion that can be made is the least surprising. Simply put, the greater the student's involvement or engagement in academic work or in the academic experience of college, the greater his or her level of knowledge acquisition and general cognitive development ... (Pascarella and Terenzini, 2005).
- Active and collaborative instruction coupled with various means to encourage student engagement invariably lead to better student learning outcomes irrespective of academic discipline (Kuh et al., 2005, 2007).

See Smith, et.al, 2005 and Fairweather, 2008, Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education - http://www7.nationalacademies.org/bose/Fairweather_CommissionedPaper.pdf

Robert Barr & John Tagg.
From teaching to learning:
A new paradigm for
undergraduate education.
Change, 27(6), 1995.

Wm. Campbell & Karl
Smith. *New Paradigms for
College Teaching*.
Interaction Books, 1997.



Comparison of Old and New Paradigm of Teaching (Johnson, Johnson & Smith, 1991)

	Old Paradigm	New Paradigm
Knowledge	Transferred from Faculty to Students	Jointly Constructed by Students and Faculty
Students	Passive Vessel to be Filled by Faculty's Knowledge	Active Constructor, Discoverer, Transformer of Knowledge
Faculty Purpose	Classify and Sort Students	Develop Students' Competencies and Talents
Relationships	Impersonal Relationship Among Students and Between Faculty and Students	Personal Transaction Among Students and Between Faculty and Students
Context	Competitive/Individualistic	Cooperative Learning in Classroom and Cooperative Teams Among Faculty
Teaching Assumption	Any Expert can Teach	Teaching is Complex and Requires Considerable Training



Johnson, D.W., Johnson, R.T., and Smith, K.A. *Active Learning: Cooperation in the College Classroom* (1st ed.). Edina, MN: Interaction Book Company, 1991.

	Old Paradigm	New Paradigm
Knowledge	Transferred from Faculty to Students	Jointly Constructed by Students and Faculty
Students	Passive Vessel to be Filled by Faculty's Knowledge	Active Constructor, Discoverer, Transformer of Knowledge
Mode of Learning	Memorizing	Relating
Faculty Purpose	Classify and Sort Students	Develop Students' Competencies and Talents
Student Goals	Complete Requirements, Achieve Certification within a Discipline	Grow, Focus on Continual Lifelong Learning within a Broader System
Relationships	Impersonal Relationship Among Students and Between Faculty and Students	Personal Transaction Among Students and Between Faculty and Students
Context	Competitive/Individualistic	Cooperative Learning in Classroom and Cooperative Teams Among Faculty
Climate	Conformity/Cultural Uniformity	Diversity and Personal Esteem/ Cultural Diversity and Commonality
Power	Faculty Holds and Exercises Power, Authority, and Control	Students are Empowered; Power is Shared Among Students and Between Students and Faculty
Assessment	Norm-Referenced (i.e., Graded "On the Curve"); Typically Multiple Choice Items; Student rating of instruction at end of course	Criterion-Referenced; Typically Performances and Portfolios; Continual Assessment of Instruction
Ways of Knowing	Logico-Scientific	Narrative
Technology Use	Drill and Practice; Textbook Substitute; Chalk and Talk Substitute	Problem Solving, Communication, Collaboration, Information Access, Expression
Teaching Assumption	Any Expert can Teach	Teaching is Complex and Requires Considerable Training

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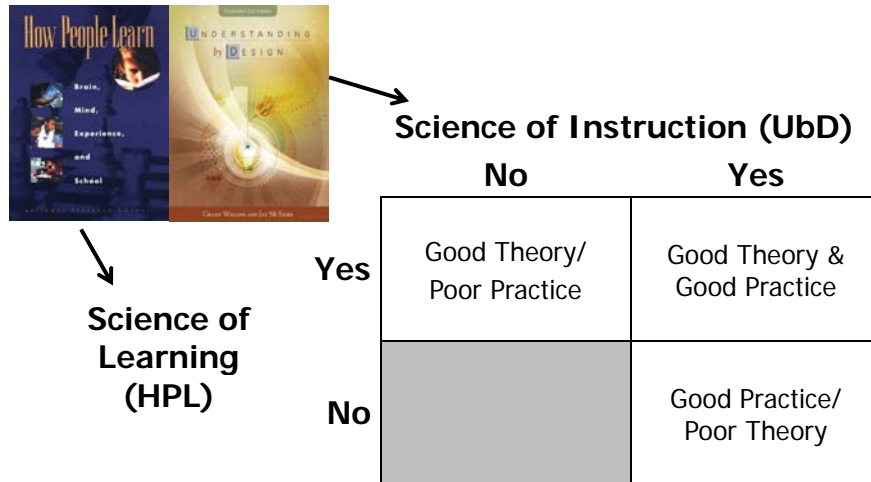
It could well be that faculty members of the twenty-first century college or university will find it necessary to set aside their roles as teachers and instead become designers of learning experiences, processes, and environments.

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

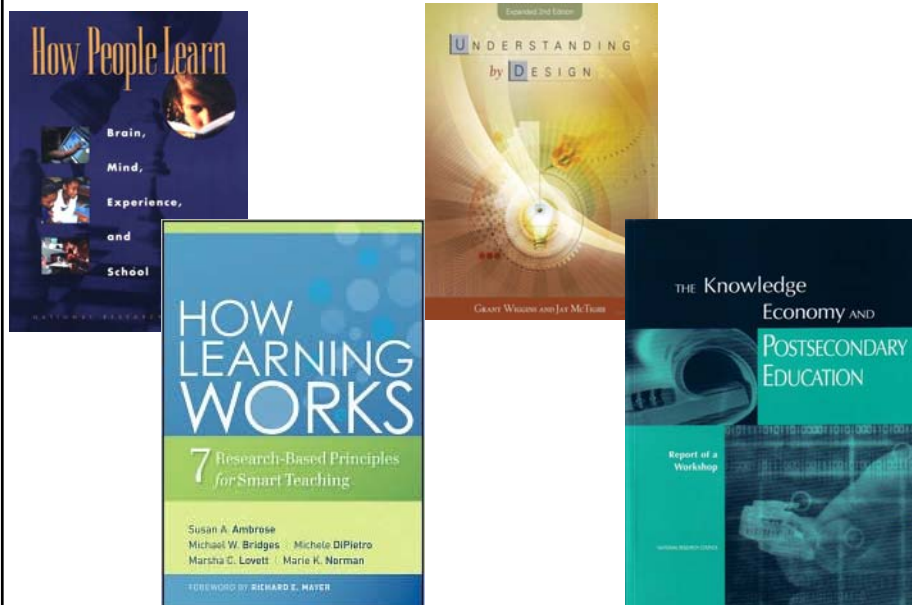


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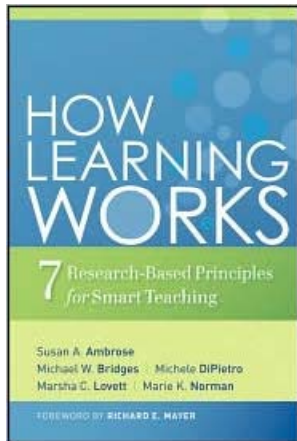
Design Foundations



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

Understanding by Design

Wiggins & McTighe (1997, 2005)

Stage 1. Identify Desired Results

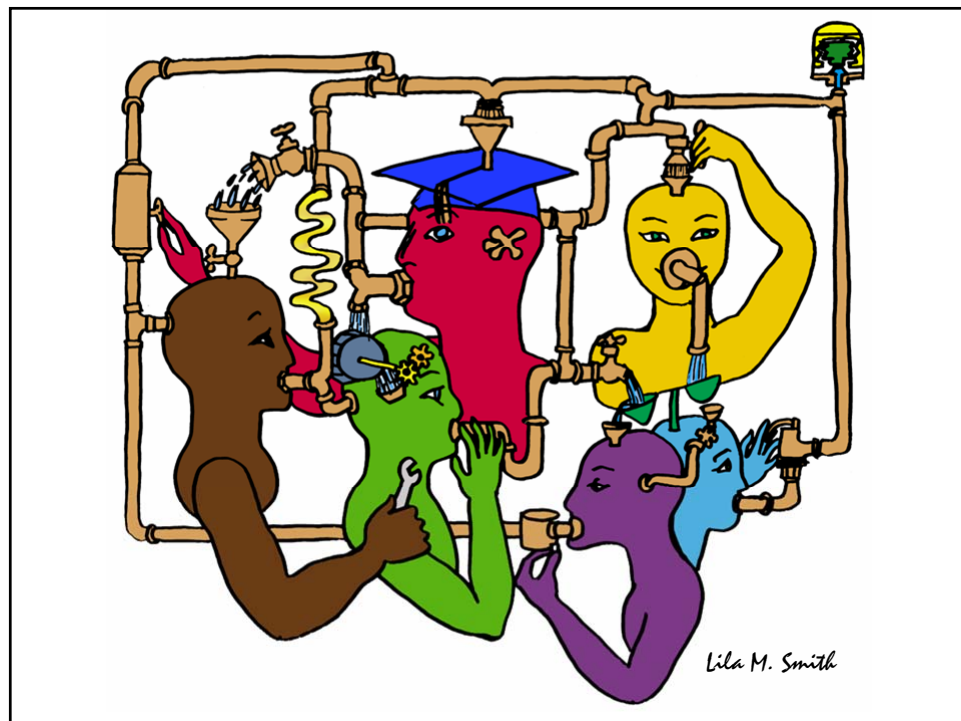
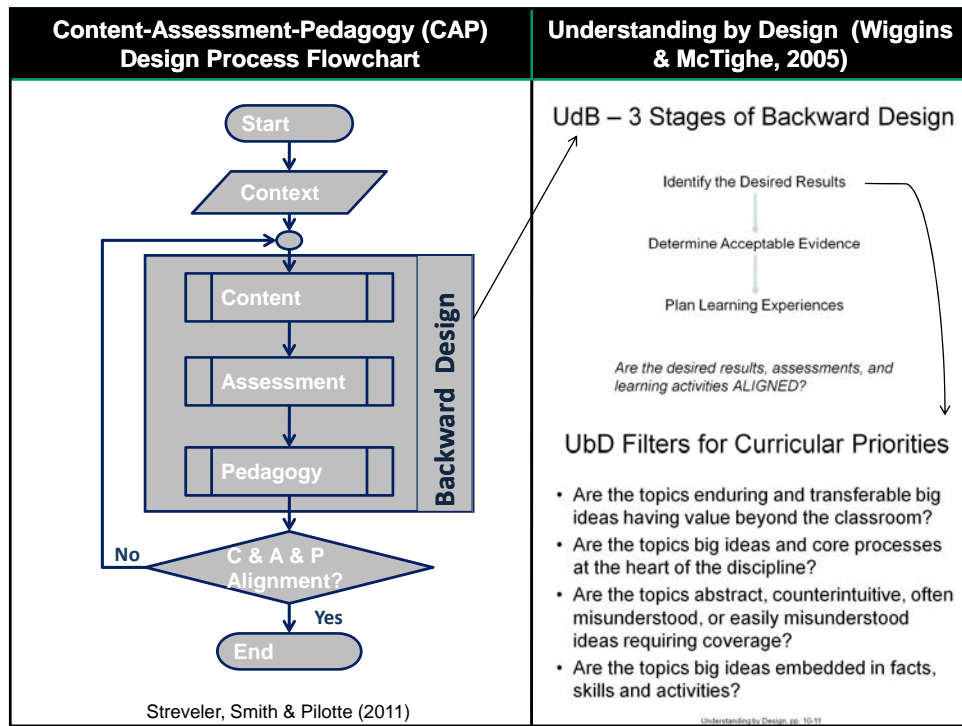
- Enduring understanding
- Important to know and do
- Worth being familiar with

Stage 2. Determine Acceptable Evidence

Stage 3. Plan Learning Experiences and Instruction

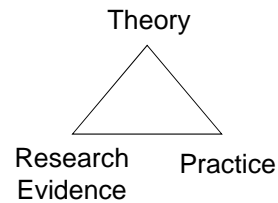
Overall: *Are the desired results, assessments, and learning activities ALIGNED?*

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



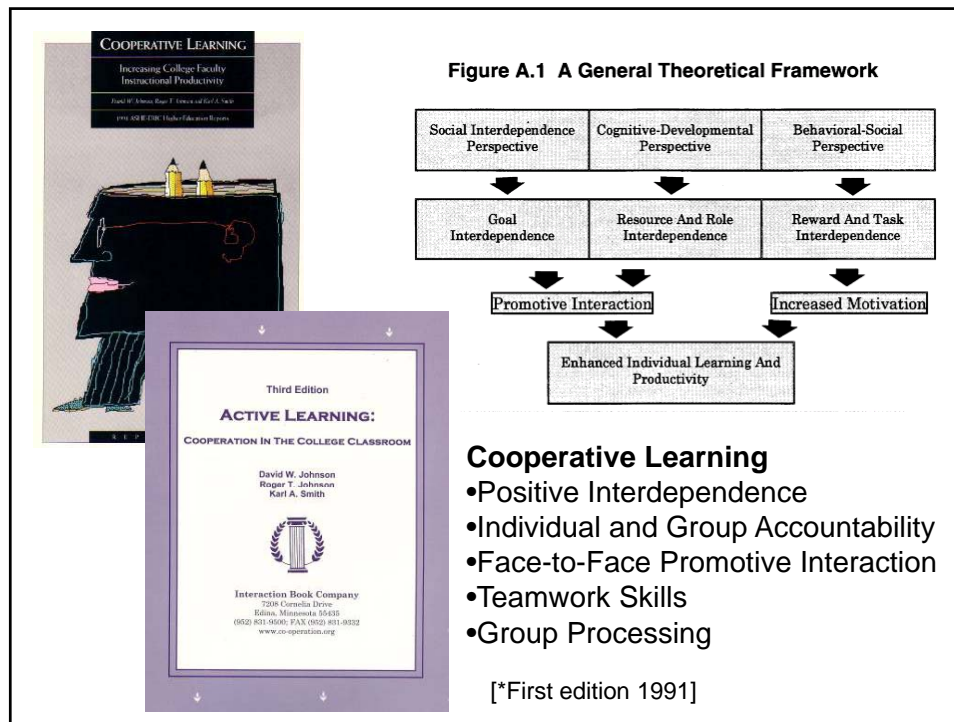
Cooperative Learning

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



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"



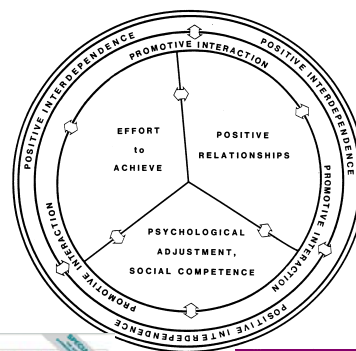
Cooperative Learning Research Support

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

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.

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

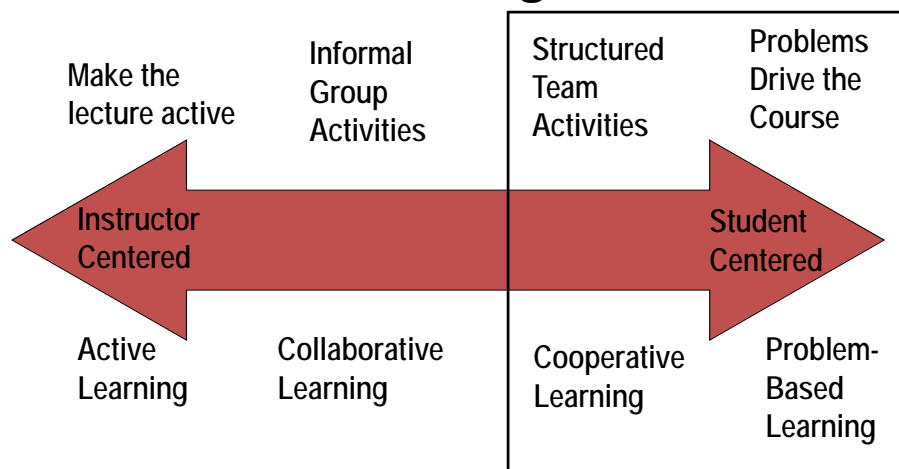
<http://www.ce.umn.edu/~smith/docs/Smith-CL%20Handout%2008.pdf>

Cooperative Learning	
Positive Interdependence	Individual Accountability
<ul style="list-style-type: none"> • All members share resources • All members share success • All members share responsibility • All members share resources • All members share success • All members share responsibility 	<ul style="list-style-type: none"> • Each member is responsible for the group's success • Each member is responsible for the group's success • Each member is responsible for the group's success • Each member is responsible for the group's success • Each member is responsible for the group's success • Each member is responsible for the group's success
Face-to-Face Interaction	Teamwork Skills
<ul style="list-style-type: none"> • Face-to-face interaction • Face-to-face interaction • Face-to-face interaction • Face-to-face interaction • Face-to-face interaction • Face-to-face interaction 	<ul style="list-style-type: none"> • Teamwork skills • Teamwork skills • Teamwork skills • Teamwork skills • Teamwork skills • Teamwork skills

Pedagogies of Engagement



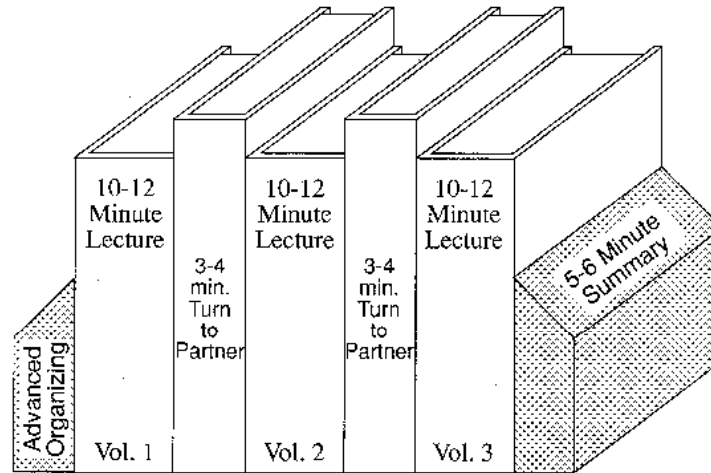
The Active Learning Continuum



Prince, M. (2010). NAE FOEE

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

Book Ends on a Class Session



10-12

Problem-Based Cooperative Learning

At M.I.T., Large Lectures Are Going the Way of the Blackboard



Josh Hillis for The New York Times
The Massachusetts Institute of Technology has changed the way it offers some introductory classes. Prof. Gabriela Sculze at a class on electricity and magnetism.

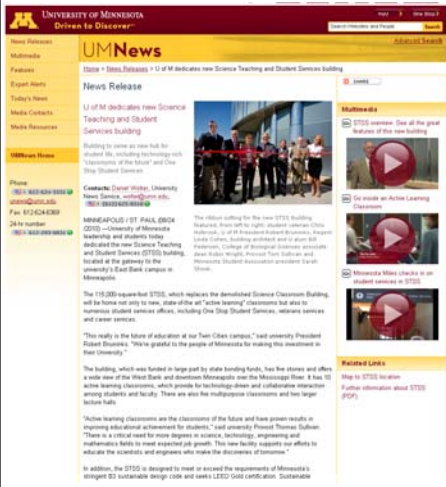
By SARA RIMER
Published: January 12, 2009

CAMBRIDGE, Mass. — For as long as anyone can remember, introductory physics at the Massachusetts Institute of Technology was taught in a vast windowless amphitheater known by its number,

COMMENTS (00)
E-MAIL
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SINGLE PAGE

January 13, 2009—New York Times — <http://www.nytimes.com/2009/01/13/us/13physics.html?em>

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UNIVERSITY OF MINNESOTA
Driven to Discover™

UMNews

News Release

U of M dedicates new Science Teaching and Student Services building

News Release

U of M dedicates new Science Teaching and Student Services building

Building to serve as new hub for student life, including technology-rich "laboratories of the future" and One Stop Student Services

Contacts: Daniel Wilton, University News Service, wilton@umn.edu, 612-625-4300

MINNEAPOLIS (ST PAUL, BROOKLYN CENTER)—University of Minnesota faculty and students today dedicated the new Science Teaching and Student Services (STSS) building, located at the gateway to the university's East Bank campus in Minneapolis.


The 115,000-square-foot STSS, which replaces the demolished Science Classroom Building, will be home not only to new "laboratories of the future" classrooms but also to numerous student services offices, including One Stop Student Services, retention services and career services.

"This really is the kind of education at our Twin Cities campus," said university President Robert Dornhoefer. "We're grateful to the people of Minnesota for making this investment in their University."

The building, which was funded in large part by state bonding funds, has the stones and offers a wide view of the West Bank and downtown Minneapolis near the Mississippi River. It has 10 active learning classrooms, which provide for technology-driven and collaborative interaction among students and faculty. There are also five multimedia classrooms and two large lecture halls.

"Active learning classrooms are the classrooms of the future and have proven results in improving educational achievement for students," said university Provost Thomas Sullivan. "There is a critical need for more degrees in science, technology, engineering and mathematics fields to meet regional job growth. This new facility supports our efforts to educate the scientists and engineers who make the difference of tomorrow."

In addition, the STSS is designed to meet or exceed the requirements of Minnesota's stringent LEED sustainable design code and meets LEED Gold certification. Sustainable



You're watching:
Inside Active Learning Classrooms


<http://mediamill.cla.umn.edu/mediamill/embed/78755>

http://www1.umn.edu/news/news-releases/2010/UR_CONTENT_248261.html

http://www.youtube.com/watch?v=IfT_hoiuY8w

http://youtu.be/IfT_hoiuY8w

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UNIVERSITY OF DELAWARE

PROBLEM-BASED LEARNING

[UD PBL articles and books](#)

[UD PBL in the news](#)

[Sample PBL problems](#)

[UD PBL courses and syllabi](#)


[PBL Clearinghouse](#)

[PBL Conferences and Other PBL sites](#)


[Institute for Transforming Undergraduate Education](#)

[Other related UD sites](#)

"How can I get my students to think?" is a question asked by many faculty, regardless of their disciplines. Problem-based learning (PBL) is an instructional method that challenges students to "learn to learn," working cooperatively in groups to seek solutions to real world problems. These problems are used to engage students' curiosity and initiate learning the subject matter. PBL prepares students to think critically and analytically, and to find and use appropriate learning resources. -- *Barbara Duch*



PBL2002:
A Pathway to Better Learning



Recipient of 1999 Hesburgh Certificate of Excellence

Please direct comments, suggestions, or requests to ud-pbl@udel.edu.
"http://www.udel.edu/pbl/"
Last updated March 13, 2004.
© Univ. of Delaware, 1999.

<http://www.udel.edu/pbl/>

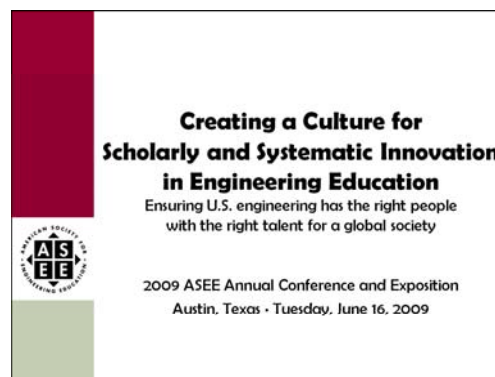
Cooperative Learning Adopted

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

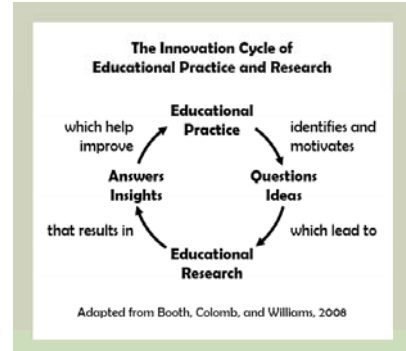
<http://www.heri.ucla.edu/index.php>

Celebration of Two Major ASEE Milestones



2011 ASEE Annual Conference and Exposition
Vancouver, British Columbia • Monday, June 27, 2011

One BIG Idea; Two Perspectives



Jamieson & Lohmann (2009)

Engineering Education Innovation

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 interdependencies 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:

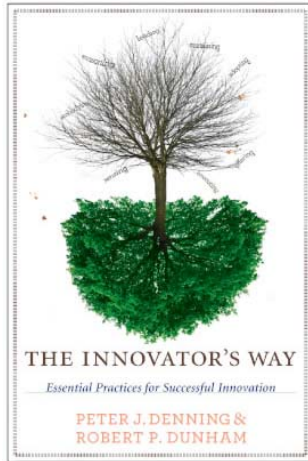
Monday's **Main Plenary** by Karl A. Smith, Cooperative Learning Professor of Engineering Education at Purdue University and Morse–Alumni Distinguished Teaching Professor & Professor of Civil Engineering at the University of Minnesota, focused on six highlighted topics (presented by six different educators)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



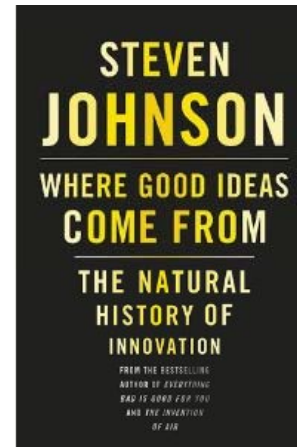
Video: <https://secure.vimeo.com/27147996>

Slides: <http://www.ce.umn.edu/~smith/links.html>

<http://www.asee.org/conferences-and-events/conferences/annual-conference/2011/program-schedule/conference-highlights>



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!**

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

Good teaching comes from the identity and integrity of the teacher.

Good teachers possess a capacity for connectedness.

Parker J. Palmer in *The courage to teach: Exploring the inner landscape of a teacher's life*. Jossey-Bass, 1998.

College Teaching: What do we know about it?

- Five assertions about what we know about college teaching
 - Good teaching makes a difference
 - Teachers vary markedly
 - Some characteristics/methods are present in all good teaching
 - Teaching can be evaluated and rewarded
 - There is ample room for improvement.
- K. Patricia Cross, 1991 ASEE ERM Distinguished Lecture

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- Four factors in good teaching, based on student ratings*:
 - Skill. Communicates in an exciting way.
 - Rapport. Understands and emphasizes with students.
 - Structure. Provides guidance to course and material.
 - Load. Requires moderate work load.
- *Student ratings of teaching are consistent (with other measures), unbiased, and useful. Students agree on good teaching and their views are consistent with faculty.

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The biggest and most long-lasting reforms of undergraduate education will come when individual faculty or small groups of instructors adopt the view of themselves as reformers within their immediate sphere of influence, the classes they teach every day.

K. Patricia Cross

The biggest and most long-lasting reforms of undergraduate education will come when individual faculty or small groups of instructors adopt the view of themselves as reformers within their immediate sphere of influence, the classes they teach every day.

K. Patricia Cross

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.
 - 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

Thank you!

An e-copy of this presentation is posted to:
<http://www.ce.umn.edu/~smith/links.html>

Worcester Polytechnic Technology – September 7, 2011



ksmith@umn.edu