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


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

**Karl A. Smith**

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STEM Education Center/Civil Eng - University of Minnesota
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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 (UbD)
    • Integrated Course Design (CAP Model)
      – Content – Assessment – Pedagogy
• Transforming Engineering Education
  – Engineering Education Innovation
  – Linking Theory, Research Evidence and Practice
• Design and Implementation

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.
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 your level familiarity with HPL & UbD?

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

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

<table>
<thead>
<tr>
<th>Science of Instruction (UbD)</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Theory/ Poor Practice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good Theory &amp; Good Practice</td>
<td></td>
<td></td>
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<tr>
<td>Good Practice/ Poor Theory</td>
<td></td>
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</tbody>
</table>

**Science of Learning (HPL)**

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


Understanding by Design


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?*

Understanding by Design (Wiggins & McTighe, 2005)

UdB – 3 Stages of Backward Design

1. Identify the Desired Results
2. Determine Acceptable Evidence
3. 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?

Context-Assessment-Pedagogy (CAP) Design Process Flowchart

Start → Context → Content → Assessment → Pedagogy → Backward Design

C & A & P Alignment? → Yes → Alignment?

End

Streveler, Smith & Pilotte (2011)

CAP Design Process (Shawn Jordan’s Model)

Start → Context → Content → Assessment → Pedagogy → Cloud of alignment

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

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)

## 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 rat 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
**The Cognitive Process Dimension**

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

(Anderson & Krathwohl, 2001).

**Changes to Bloom’s**

1956

- Evaluation
- Synthesis
- Analysis
- Application
- Comprehension
- Knowledge

2001

- Create
- Evaluate
- Analyze
- Apply
- Understand
- Remember

Noun to Verb Form

http://www.uwsp.edu/education/lwilson/curric/newtaxonomy.htm
**A TAXONOMY OF SIGNIFICANT LEARNING**

<table>
<thead>
<tr>
<th>Cognitve</th>
<th>Affective</th>
<th>Meta</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Foundational Knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Understand and remember&quot; learning</td>
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<tr>
<td>For example: facts, terms, formulae, concepts, principles, etc.</td>
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<tr>
<td>2. Application</td>
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<tr>
<td>Thinking: critical, creative, practical (problem-solving, decision-making)</td>
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<tr>
<td>Other skills</td>
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<tr>
<td>For example: communication, technology, foreign language</td>
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<tr>
<td>Managing complex projects</td>
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<tr>
<td>3. Integration</td>
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<tr>
<td>Making “connections” (i.e., finding similarities or interactions) . . .</td>
<td></td>
<td></td>
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<tr>
<td>Among: ideas, subjects, people</td>
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<tr>
<td>4. Human Dimensions</td>
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<tr>
<td>Learning about and changing one's SELF</td>
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<tr>
<td>Understanding and interacting with OTHERS</td>
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<tr>
<td>5. Caring</td>
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<td></td>
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<tr>
<td>Identifying/changing one's feelings, interests, values</td>
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<tr>
<td>6. Learning How to Learn</td>
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<tr>
<td>Becoming a better student</td>
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<tr>
<td>Learning how to ask and answer questions</td>
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<td></td>
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<tr>
<td>Becoming a self-directed learner</td>
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</tbody>
</table>

**3 Stages of Understanding by Design**

1. Identify the Desired Results
2. Determine Acceptable Evidence
3. Plan Learning Experiences

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

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

*What materials and resources will be useful?*
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
- ASEE Annual Conference – Main Plenary – 2011
- NAE Frontiers of Engineering Education (FOEE)
  - http://www.nae.edu/Activities/Projects20676/CASEE/26338/35816/FOEE.aspx

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
Cyclic Model for Creating Knowledge and Improving Practices in STEM Education

New Materials and Strategies

Research on Teaching and Learning

Assess and Evaluate

Increase Faculty Expertise

Implement Innovations

Engineering Education Innovation

One BIG Idea; Two Perspectives

Jamieson & Lohmann (2009)
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 3,000 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 reflect 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.

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-scheduleconference-highlights

Creating a Culture for Scholarly and Systematic Innovation in Engineering Education
Ensuring U.S. engineering has the right people with the right talent for a global society
2009 ASEE Annual Conference and Exposition
Austin, Texas · Thursday, June 14, 2009
Engineering Education Innovation
Karl Smith

Research
• 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


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

\[ (\nabla c \bullet \nabla) = D\nabla^2 c \]

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

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 – ?

Diagram:
- Theory
- Research
- Evidence
- Practice
Cooperative Learning

- Research – Randomized Design Field Experiments
- Practice – Formal Teams/Professor’s Role
Cooperative Learning

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

[First edition 1991]

Cooperative Learning Research Support


- 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
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


Cooperative Learning Introduced to Engineering – 1981


JEE December 1981
Cooperative Learning Adopted
The American College Teacher:
National Norms for 2007-2008

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

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

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

Instructor Centered

Active Learning

Collaborative Learning

Cooperative Learning

Problem-Based Learning

Student Centered

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!
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 (UbD) Process

- Content Resources

- Cooperative Learning
  - Cooperative Learning (Johnson, Johnson & Smith) - Smith web site – www.ce.umn.edu/~smith

- Other Resources
  - University of Delaware PBL web site – www.udel.edu/pbl
  - PKAL – Pedagogies of Engagement – http://www.pkal.org/PKAL/pedagogy KittlesCollegeSummit.rtf

Thank you!

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

NAE Frontiers of Engineering Education, November 15, 2011

ksmith@umn.edu