Design and Implementation of Pedagogies of Engagement: Cooperative Learning and Challenge-Based Learning

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

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Session Layout

• Welcome & Overview
• Course Design Foundations
  – Understanding by Design (UdB)
  • Integrated Course Design (CAP Model)
    – Content – Assessment – Pedagogy
  – How People Learn (HPL)
    • How Learning Works (Ambrose, et al.)
• Pedagogies of Engagement – Cooperative Learning and Challenge Based Learning
  – Informal – Bookends on a Class Session
  – Formal Cooperative Learning
• Design and Implementation
Workshop Objectives

• Participants will be able to
  – Explain rationale for Pedagogies of Engagement, especially Cooperative Learning & Challenge Based Learning
  – Describe key features of Cooperative Learning
  – Apply cooperative learning to classroom practice
  – Describe key features of the Understanding by Design and How People Learn
  – Identify connections between cooperative learning and desired outcomes of courses and programs

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>
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<tbody>
<tr>
<td>Good Theory/ Poor Practice</td>
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<td>Good Theory &amp; Good Practice</td>
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<table>
<thead>
<tr>
<th>Science of Learning (HPL)</th>
<th>No</th>
<th>Yes</th>
</tr>
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<tbody>
<tr>
<td>Good Practice/ Poor Theory</td>
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**Sources:**

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


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  

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?


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<thead>
<tr>
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<tbody>
<tr>
<td>Start</td>
<td>UdB – 3 Stages of Backward Design</td>
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<tr>
<td>Context</td>
<td>Identify the Desired Results</td>
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<tr>
<td></td>
<td>Determine Acceptable Evidence</td>
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<tr>
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<td>Plan Learning Experiences</td>
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<tr>
<td></td>
<td>Are the desired results, assessments, and learning activities ALIGNED?</td>
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<tr>
<td>Content</td>
<td>C &amp; A &amp; P Alignment?</td>
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<tr>
<td>Assessment</td>
<td></td>
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<tr>
<td>Pedagogy</td>
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<tr>
<td></td>
<td>Yes</td>
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<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Streveler, Smith &amp; Pilotte (2011)</td>
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</tbody>
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UdB 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?
“Throughout the whole enterprise, the core issue, in my view, is the mode of teaching and learning that is practiced. Learning ‘about’ things does not enable students to acquire the abilities and understanding they will need for the twenty-first century. We need new pedagogies of engagement that will turn out the kinds of resourceful, engaged workers and citizens that America now requires.”

Russ Edgerton (reflecting on higher education projects funded by the Pew Memorial Trust)

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

Reflection and Dialogue

- Individually reflect on your familiarity with (1) Integrated Course Design and (2) Pedagogies of Engagement, especially Cooperative Learning. Write for about 1 minute
  - Key ideas, insights, applications – Success Stories
  - Questions, concerns, challenges
- Discuss with your neighbor for about 3 minutes
  - Select one Insight, Success Story, Comment, Question, etc. that you would like to present to the whole group if you are randomly selected

Understanding by Design

Stage 2. Determine Acceptable Evidence

Types of Assessment

Quiz and Test Items:
- Simple, content-focused test items

Academic Prompts:
- Open-ended questions or problems that require the student to think critically

Performance Tasks or Projects:
- Complex challenges that mirror the issues or problems faced by graduates, they are authentic
Feedback and Assessment

• Forward Looking Assessment
  – Questions that incorporate course concepts in a real-life context
• Criteria and Standards
  – What traits or characteristics are indicative of high quality work?
• Self-Assessment
  – Allow students to gauge their own learning.
• FIDeLity Feedback
  – Frequent, Immediate, Discriminating, Lovingly delivered

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

20 (Anderson & Krathwohl, 2001)
Understanding by Design

Stage 3. Plan Learning Experiences & Instruction

- What enabling knowledge (facts, concepts, and principles) and skills (procedures) will students need to perform effectively and achieve desired results?
- What activities will equip students with the needed knowledge and skills?
- What will need to be taught and coached, and how should it be taught, in light of performance goals?
- What materials and resources are best suited to accomplish these goals?
- Is the overall design coherent and effective?
Active Learning: Cooperation in the College Classroom

- **Informal** Cooperative Learning Groups
- **Formal** Cooperative Learning Groups
- Cooperative **Base** Groups

See Cooperative Learning Handout (CL College-804.doc)

Book Ends on a Class Session

10-12 Minute Lecture
3-4 min. Turn to Partner
10-12 Minute Lecture
3-4 min. Turn to Partner
10-12 Minute Lecture
5-6 Minute Summary
Book Ends on a Class Session

1. Advance Organizer
2. Formulate-Share-Listen-Create (Turn-to-your-neighbor) -- repeated every 10-12 minutes
3. Session Summary (Minute Paper)
   1. What was the most useful or meaningful thing you learned during this session?
   2. What question(s) remain uppermost in your mind as we end this session?
   3. What was the "muddiest" point in this session?

Advance Organizer
“The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.”

David Ausubel - Educational psychology: A cognitive approach, 1968.
Quick Thinks

• Reorder the steps
• Paraphrase the idea
• Correct the error
• Support a statement
• Select the response


Formulate-Share-Listen-Create

Informal Cooperative Learning Group
Introductory Pair Discussion of a

FOCUS QUESTION

1. Formulate your response to the question individually
2. Share your answer with a partner
3. Listen carefully to your partner's answer
4. Work together to Create a new answer through discussion

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Minute Paper

- What was the most useful or meaningful thing you learned during this session?
- What question(s) remain uppermost in your mind as we end this session?
- What was the “muddiest” point in this session?
- Give an example or application
- Explain in your own words . . .


Session Summary
(Minute Paper)

Reflect on the session:

1. Most interesting, valuable, useful thing you learned.
2. Things that helped you learn.
3. Question, comments, suggestions.

4. Pace: Too slow 1 . . . . 5 Too fast
5. Relevance: Little 1 . . . 5 Lots
6. Instructional Format: Ugh 1 . . . 5 Ah
Minute Paper – Reflection

1. Most interesting, valuable, useful thing you learned.
2. Question/Topic/Issue you would like to have addressed
3. Current challenge, comments, suggestions, etc.
4. Pace: Too Slow 1 2 3 4 5 Too Fast
5. Relevance: Low 1 2 3 4 5 High
6. Discussion Control: Too Low 1 2 3 4 5 Too High
Q4 – Pace: Too slow 1 . . . 5 Too fast (3.1)
Q5 – Relevance: Little 1 . . . 5 Lots (4.2)
Q6 – Discussion Control: Too Low 1 . . . 5 Too High (3.3)

Q4 – Pace: Too slow 1 . . . 5 Too fast (3.0)
Q5 – Relevance: Little 1 . . . 5 Lots (3.9)
Q6 – Format: Ugh 1 . . . 5 Ah (4.1)
Informal CL (Book Ends on a Class Session) with Concept Tests

Physics
Peer Instruction
Peer Instruction – www.prenhall.com
Richard Hake – http://www.physics.indiana.edu/~hake/

Chemistry
Chemistry ConcepTests - UW Madison
www.chem.wisc.edu/~concept
Video: Making Lectures Interactive with ConcepTests
ModularChem Consortium – http://mc2.chem.berkeley.edu/

STEMTEC

Harvard – Derek Bok Center

The “Hake” Plot of FCI

![The “Hake” Plot of FCI](image)
Richard Hake (Interactive engagement vs traditional methods)
http://www.physics.indiana.edu/~hake/

Fig. 2. Histogram of the average normalized gain $\langle g \rangle$: dark (red) bars show the fraction of 14 traditional courses ($N = 2084$), and light (green) bars show the fraction of 48 interactive engagement courses ($N = 4458$), both within bins of width $\Delta g = 0.04$ centered on the $\langle g \rangle$ values shown.

III. CONCEPTUAL TEST RESULTS
A. Gain vs Pretest Graph - All Data

Fig. 1. $\%$ Gain vs $\%$ Pretest score on the conceptual Mechanics Diagnostic (MD) or Force Concept Inventory (FCI) tests for all 62 courses enrolling a total $N = 4042$ students: 14 traditional (T) courses ($N = 2084$) which made little or no use of interactive engagement (IE) methods, and 48 IE courses ($N = 1958$) which made considerable use of IE methods. Superimposed for the averages of the 14 T courses $\langle g \rangle = 0.14$ and of IE courses $\langle g \rangle = 0.14$ are shown, as explained in the text.
Physics (Mechanics) Concepts: The Force Concept Inventory (FCI)

- A 30 item multiple choice test to probe student's understanding of basic concepts in mechanics.
- The choice of topics is based on careful thought about what the fundamental issues and concepts are in Newtonian dynamics.
- Uses common speech rather than cueing specific physics principles.
- The distractors (wrong answers) are based on students' common inferences.

Informal Cooperative Learning Groups

Can be used at any time
Can be short term and ad hoc
May be used to break up a long lecture
Provides an opportunity for students to process material they have been listening to (Cognitive Rehearsal)
Are especially effective in large lectures
Include "book ends" procedure
Are not as effective as Formal Cooperative Learning or Cooperative Base Groups
Active Learning: Cooperation in the College Classroom

- **Informal** Cooperative Learning Groups
- **Formal** Cooperative Learning Groups
- Cooperative **Base** Groups

See Cooperative Learning Handout (CL College-804.doc)
Formal Cooperative Learning
Task Groups

Most Important Skills Employers
Look For In New Hires
Which TWO of the following skills or abilities are most important to you?

<table>
<thead>
<tr>
<th>Skill</th>
<th>Recent Grade</th>
</tr>
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<tbody>
<tr>
<td>Teamwork skills</td>
<td>44%</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>38%</td>
</tr>
<tr>
<td>Oral/written communication</td>
<td>37%</td>
</tr>
<tr>
<td>Ability to assemble/organize information</td>
<td>37%</td>
</tr>
<tr>
<td>Innovative/creativity</td>
<td>21%</td>
</tr>
<tr>
<td>Able to work with numbers/statistics</td>
<td>15%</td>
</tr>
<tr>
<td>Foreign language proficiency</td>
<td>11%</td>
</tr>
</tbody>
</table>

* Skills that most presidents think are the two most important to employers

### Top Three Main Engineering Work Activities

**Engineering Total**
- Design – 36%
- Computer applications – 31%
- Management – 29%

**Civil/Architectural**
- Management – 45%
- Design – 39%
- Computer applications – 20%


### Teamwork Skills

- Communication
- Listening and Persuading
- Decision Making
- Conflict Management
- Leadership
- Trust and Loyalty
Professor's Role in Formal Cooperative Learning

1. Specifying Objectives
2. Making Decisions
3. Explaining Task, Positive Interdependence, and Individual Accountability
4. Monitoring and Intervening to Teach Skills
5. Evaluating Students' Achievement and Group Effectiveness
Formal Cooperative Learning – Types of Tasks

1. Jigsaw – Learning new conceptual/procedural material
2. Peer Composition or Editing
3. Reading Comprehension/Interpretation
4. **Problem Solving, Project, or Presentation**
5. Review/Correct Homework
6. Constructive Academic Controversy
7. Group Tests

Challenge-Based Learning

- Problem-based learning
- Case-based learning
- Project-based learning
- Learning by design
- Inquiry learning
- Anchored instruction

John Bransford, Nancy Vye and Helen Bateman. Creating High-Quality Learning Environments: Guidelines from Research on How People Learn
Challenge-Based Instruction with the Legacy Cycle

The Challenges

1. Generate Ideas
2. Multiple Perspectives
3. Research & Revise
4. Test Your Mettle
5. Go Public

Legacy Cycle

https://repo.vanth.org/portal/public-content/star-legacy-cycle/star-legacy-cycle

Problem-Based Learning

START

Problem posed

Identify what we need to know

Learn it

Apply it
Problem-Based Cooperative Learning

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

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,

http://web.mit.edu/edtech/casestudies/teal.html#video
The SCALE-UP Project...  

This research was supported in part by the U.S. Department of Education under the Improvement of Post-Secondary Education (I-PSEA) Title V - National Science Foundation (NSF) grant EEC-0410735.  

Impact:  

In recent years the learning experiences that students encounter in science, technology, engineering, and mathematics (STEM) courses are often not optimized for active learning. A key finding in the literature is that learning is enhanced when students are actively engaged. The SCALE-UP Project is a curriculum development project designed to bring active learning to undergraduates. The SCALE-UP Project works with teams of undergraduate STEM majors to develop and implement new curricula that emphasize active learning. The project provides training for instructors and supports teams of students in designing and implementing new courses. The project also provides tools and resources to help instructors implement active learning in their courses. The goal is to improve student learning and engagement through active learning.  

Details:  

At the core of the SCALE-UP project is the concept of "small active learning teams." These teams are typically made up of 4 to 6 students and meet once a week to discuss the content of the course. The teams are led by a faculty member who is trained in active learning and is available to provide support and guidance. The teams are evaluated using a variety of tools, including pre- and post-tests, surveys, and interviews. The project also provides resources to help instructors implement active learning in their courses.  

http://www.ncsu.edu/PER/scaleup.html

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


http://www.youtube.com/watch?v=lfT_hoiuY8w

http://youtu.be/lfT_hoiuY8w
Problem-Based Cooperative Learning

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Estimation Exercise
First Course Design Experience
UMN – Institute of Technology

- Thinking Like an Engineer
- Problem Identification
- Problem Formulation
- Problem Representation
- Problem Solving

Problem-Based Learning

*Based on First Year Engineering course – Problem-based cooperative learning approach published in 1990.
Problem Based Cooperative Learning Format

TASK: Solve the problem(s) or Complete the project.

INDIVIDUAL: Estimate answer. Note strategy.

COOPERATIVE: One set of answers from the group, strive for agreement, make sure everyone is able to explain the strategies used to solve each problem.

EXPECTED CRITERIA FOR SUCCESS: Everyone must be able to explain the strategies used to solve each problem.

EVALUATION: Best answer within available resources or constraints.

INDIVIDUAL ACCOUNTABILITY: One member from your group may be randomly chosen to explain (a) the answer and (b) how to solve each problem.

EXPECTED BEHAVIORS: Active participating, checking, encouraging, and elaborating by all members.

INTERGROUP COOPERATION: Whenever it is helpful, check procedures, answers, and strategies with another group.

Cooperative Base Groups

- Are Heterogeneous
- Are Long Term (at least one quarter or semester)
- Are Small (3-5 members)
- Are for support
- May meet at the beginning of each session or may meet between sessions
- Review for quizzes, tests, etc. together
- Share resources, references, etc. for individual projects
- Provide a means for covering for absentees
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

The Active Learning Continuum

Prince, M. (2010). NAE FOEE

*My work is situated here – Cooperative Learning & Challenge-Based Learning*
Design and Implementation of Cooperative Learning – Resources

- Design Framework – How People Learn (HPL) & Backward Design Process
  - Pellegrino – Rethinking and redesigning curriculum, instruction and assessment: What contemporary research and theory suggests

- Content Resources

- Cooperative Learning - Instructional Format explanation and exercise to model format and to engage workshop participants
  - 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