Design and Implementation of Evidence-based Practices in Engineering Education

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It is strange that we expect students to learn, yet seldom teach them anything about learning. We expect students to solve problems, yet seldom teaching them anything about problem solving. And, similarly, we sometimes require students to remember A considerable body of material, yet seldom teach them the art of memory. It is time we Made up for this lack…

D.A. Norman. 1980. Cognitive engineering and education. In D.T. Tuma and F. Reif (Eds.), *Problem solving and education: Issues in teaching and research. Erlbaum, pp. 97-107.*

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Learning Requires*

deliberate

distributed

practice

***Thanks to Ruth Streveler for these slides**

Also see Brown, P.C., Henry L. Roediger III, H.L., & Mark A. McDaniel, M.A. (2014). *Make It Stick: The Science of Successful Learning*. Belknap Press: An Imprint of Harvard University Press

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Key Implications

Deliberate

Attention must be paid

Attention and processing power = cognitive load (bandwidth)

- LIMITED – need to be careful how one uses the learner's bandwidth
  - Link to Curricular Priorities
- Continuous partial attention

- Reflection is needed
  - Need for feedback
    - Link to assessment

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Key Implications

Distributed

Repetition over time
- Spaced vs. massed practice*
- Spiral curriculum

Multiple modes of input
- Visual
- Audio
- Kinesthetic
- Self-explanation
- Explaining to others

*Kandel, E.B. 2007. In Search of Memory: The Emergence of a New Science of Mind. New York: Norton.

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Key Implications

Practice what you want to learn

Active (Attentive) – doing something

Constructive – adding to your prior knowledge

Interactive – working with others to add to your prior knowledge

Chi, M.T.H. 2009. Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science 1*, 73–105.

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Session Layout

Welcome & Overview

Three BIG IDEAS (Enduring Outcomes)
- Streamlined Course Design
- Alignment of Outcomes, Assessment and Instruction
- Interactive Learning

Streamlined Course Design
- Course outcomes planning form
- Course Concept Map

Assessment Overview
- Types of assessment
- Writing learning objectives
- Mapping objectives on a taxonomy exercise

Interactive (Cooperative) Learning
- Description & Rationale
- Cooperative Learning
  - Key Concepts
  - Types of Cooperative Learning
- Informal Cooperative Learning planning exercise

Implementing Evidence-Based Instructional Practices
- Practice
- Examples
- Applications

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Big Ideas (Enduring Outcomes)

- How People Learn
- Streamlined Course Design
  - Alignment of Outcomes, Assessment and Instruction
- **Interactive Learning**

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Streamlined Course Design

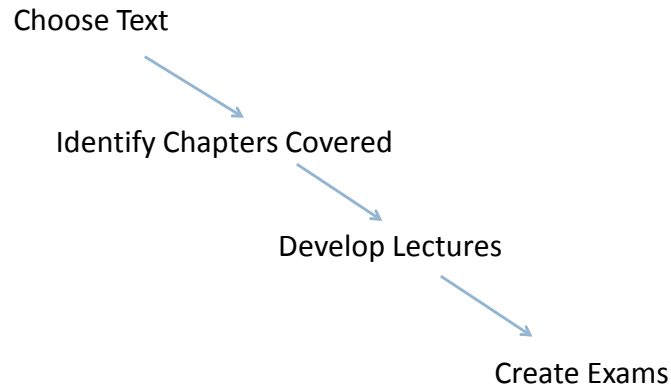
Streamlined Course Design is a guided process that is based on the engineering design process.

The end product Streamlined Course Design is a course where what is learned, how that learning is measured, and the learning environment are all aligned.

Why Streamline?

- Aligned courses — students are learning what "matters" and you have evidence about their learning
- Increased student learning — about the things that matter
- Increased satisfaction by instructors and students about their experience in the course

Version 0 - What is the Common Instructional Design Approach?



Our Assertion

Course design should follow the engineering design process

Our next questions:

- What is the engineering design process?
- How does course design map to the engineering design process?

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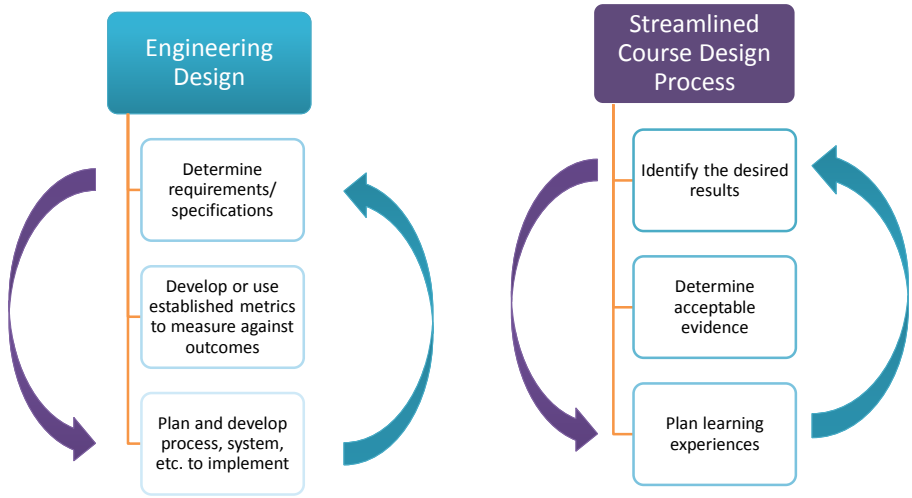
The Engineering Design Process vs. Streamlined Course Design Process



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Curricular Priorities: What are they?

First – how do you want your students to be different when they leave the class? What should they know, be able to do, care about?

Second – how can you rank what you listed in #1 as most important?

Wiggins and McTighe called these "curricular priorities"

- Enduring outcomes – enduring long after the course is over
- Important to know – KSA needed to arrive at the enduring outcomes
- Good to be familiar with – good if they can recognize, but nothing vital

Note these are not necessarily written as LEARNING OBJECTIVES (that is a separate step).

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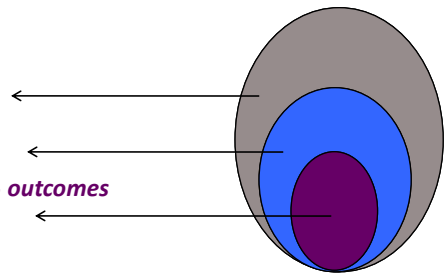
Curricular Priorities

Categorize outcomes into three levels

Good to be familiar with

Important to know

Enduring ~~understandings~~ *outcomes*



From Wiggins and McTighe

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How to Determine Curricular Priorities

Big ideas:

- What lies at the heart of the discipline?
- What do professionals/experts do?

Essential questions:

- What questions do you want your students to ask as they learn the material?

What are the *guiding concepts* and how do those concepts *relate* to one another?

- A graphic like a concept map is one way to discover relationships

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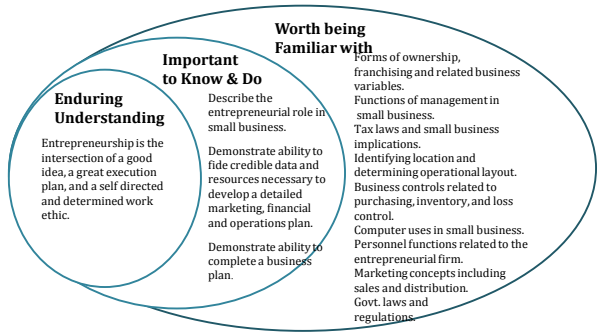
Engineering Entrepreneurship Curricular Priorities



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Curricular Priorities Worksheet

1. List curricular priorities of the course you want to (re)design – see Handout ~ 5 minutes
   1. Enduring outcomes
   2. Important to know outcomes
   3. Good to be familiar with outcomes
2. Share and discuss curricular priorities with your group ~10 min

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Curricular Priorities Worksheet – Part 2

1. List curricular priorities of the course you want to (re)design – see Handout
   1. Enduring outcomes
   2. Important to know outcomes
   3. Good to be familiar with outcomes
2. Create a concept map of the course that includes enduring outcomes, important to know, and good to be familiar with items.

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What are concept maps and why use them?

What are concept maps?

- Concept maps are graphical tools for organizing and representing knowledge (http://cmap.ihmc.us).

Why use concept maps?

- They are a tool for helping you think about how the concepts in your target domain are connected.
- They help you discover what is most important – thus are useful for determining curricular priorities and for identifying difficult or threshold concepts.

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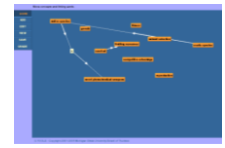
Concept Maps Software Tools

FREE

Cmap Tools (http:// cmap.ihmc.us)

- Institute for Human &Machine Cognition
- Free downloadable program
- Site also has links to instructional videos on how to use Cmap

Commercial software with free trials



Inspiration

- http://www.inspiration.com/

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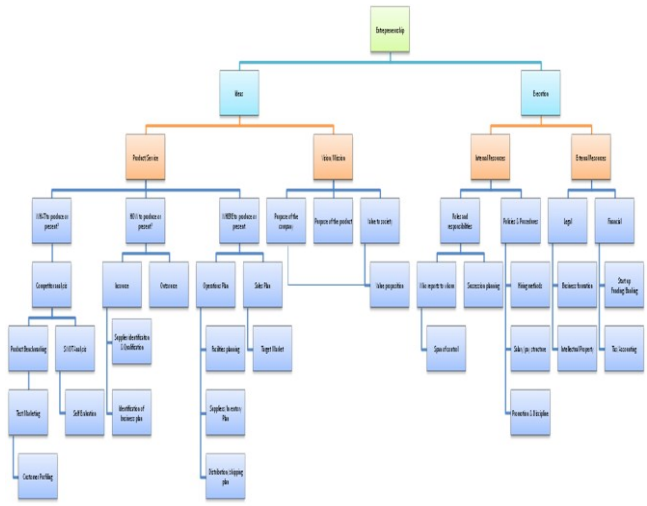
Example of concept maps

Engineering Entrepreneurship First Concept Map



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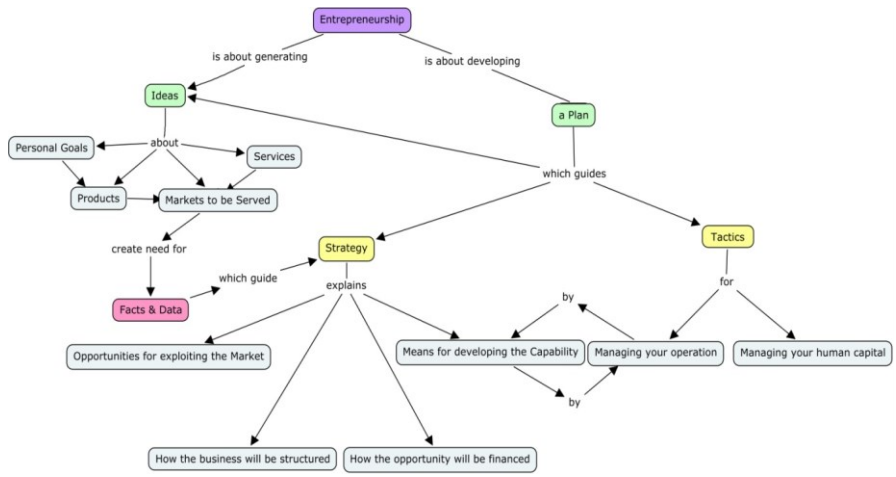
Engineering Entrepreneurship Second Iteration of Concept Map



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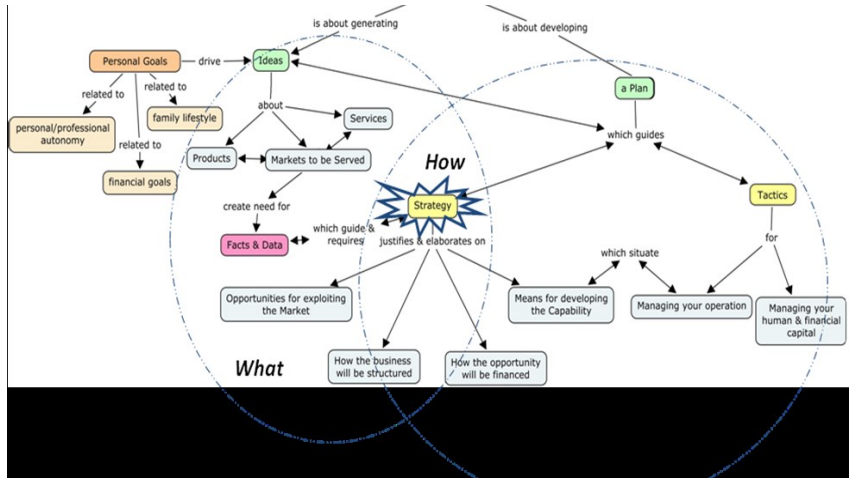
Engineering Entrepreneurship Third Iteration of Concept Map



Learning Objectives = the bridge between content and assessment

WHY?

- Learning objectives are the mechanism for making the learning MEASURABLE. So you CAN assess it!

What? Learning objectives are statements that are:

- **S**pecific
- **M**easurable (Describable)
- **A**ttainable
- **R**elevant
- **T**ime-bound

Why assess?

Designer's perspective:

- Assessment is the measure YOU need to know if your design is working as you would like it to.
- Analogous to the measuring against the specs of a technical design.
  - Writing learning objective is like writing the specs.

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Why assess?

Learners' perspective

- How will LEARNERS know they learned the material?
- How will LEARNERS reflect on what they have practiced?
- How will LEARNERS be able to practice what they need to learn?

Assessment as:

- A form of learning
- A form of reflection
- A form of deliberate, distributed practice

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Types of Assessment

1. **Diagnostic Assessment**
   Conducted at the beginning of an instructional unit, course, semester. . . to determine the present level of knowledge, skill, interest. . . of a student, group or class.

2. **Formative Assessment**
   Conducted periodically throughout the instructional unit. . .to monitor progress and provide feedback toward learning goals.

3. **Summative Assessment**
   Conducted at the end of an instructional unit or semester to judge the quality and quantity of student achievement and/or the success of the instructional unit.

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Making Assessments Meaningful

1. To be meaningful, assessment has to have a purpose that is significant

2. Meaningful assessments provide a direction and road map for future efforts to learn.

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Writing Learning Objectives

1. WHEN DO YOU WRITE LEARNING OBJECTIVES?
2. HOW DO YOU WRITE LEARNING OBJECTIVES?
3. EXAMPLES
4. NOW YOU TRY!

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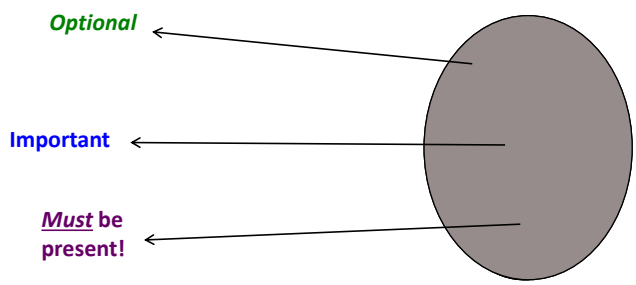
When Do You Write Learning Objectives

Learning Objectives

Curricular Priorities



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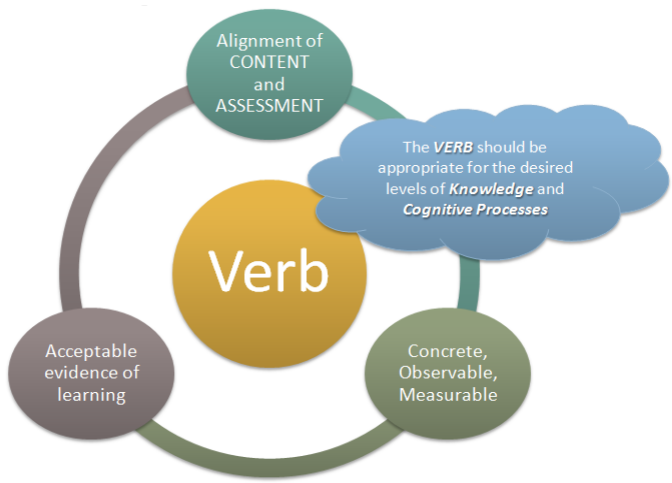
Constructing Learning Objectives
Using Verb-Noun Format



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Writing examples

At the end of this course, students will:

- Understand the importance of contextual features
- Understand the importance of contextual features for product design
- Explain in plain language why is it important to consider contextual features in the design of a product
- Design (a product X) for (a particular user/population Y)

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Activity: Writing Learning Objectives for your Curricular Priorities

Total Activity Time: ~15 minutes

Part 1: Individual Exercise (5 minutes)

Part 2: Small Group Discussion (10 minutes)

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Activity Part I (5 Minutes): Write your Learning Objectives (LO)s

On your own, write LOs for your *enduring outcomes* first. If time allows, try to write one LO for an *important to know* piece of your curricular priorities

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Activity Part II (10 Minutes) Discuss with your Group

Share your learning objectives (LOs) with your breakout group. Do your LOs seem *SMART* and well-written to your peers?

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Question

Do you use a taxonomy of learning objectives? If yes, which one?

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Taxonomies of Learning Objectives

What is a taxonomy?

How do you use them?

Why are they useful?

When do you use them?

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Taxonomies of Learning Objectives

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).

Taxonomy of significant learning (Fink, 2003)

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

Facets of understanding (Wiggins & McTighe, 1998)

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Anderson and Krathwohl taxonomy

AN UPDATED VERSION OF BLOOM'S TAXONOMY

Revised Bloom's Taxonomy

The Cognitive Process Dimension represents a continuum of increasing cognitive complexity—from lower order thinking skills to higher order thinking skills. Anderson and Krathwohl (2001) identify nineteen specific cognitive processes that further clarify the scope of the six categories (Table 2).

Table 2. The Cognitive Processes dimension — categories & cognitive processes and alternative names

lower order thinking skills → higher order thinking skills

remember	understand	apply	analyze	evaluate	create
recognizing • identifying recalling • retrieving	interpreting • clarifying • paraphrasing • representing • translating exemplifying • illustrating • instantiating classifying • categorizing • subsuming summarizing • abstracting • generalizing inferring • concluding • extrapolating • interpolating • predicting comparing • contrasting • mapping • matching explaining • constructing models	executing • carrying out implementing • using	differentiating • discriminating • distinguishing • focusing • selecting organizing • finding coherence • integrating • outlining • parsing • structuring attributing • deconstructing	checking • coordinating • detecting • monitoring • testing critiquing • judging	generating • hypothesizing planning • designing producing • constructing

(Table 2 adapted from Anderson and Krathwohl, 2001, pp. 67–68.)

http://www.celt.iastate.edu/wp-content/uploads/2015/09/RevisedBloomsHandout-1.pdf

Examples of Objectives that Map to Bloom

1. List the six levels of the revised Bloom's taxonomy
2. Explain in your own words the first three levels
3. Map the following learning objectives to a level on Bloom's taxonomy:

   At the end of the course, students will be able to
   - Solve mass transfer problems using Fick's law
   - Enumerate the essential components in a control loop
   - Build a functional prototype of a membrane separation system for a set of given operating conditions

Adapted from Michael Prince's Workshop "*How to engineer engineering education*", July 2016

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Examples of Objectives that Map to Bloom

4. An instructor wrote the following learning objective for an enduring outcome:

   Classify different forms of assessment into authentic or non authentic

   Does it sound appropriate? Could you improve it?
5. Choose the appropriate level on Bloom's taxonomy for the outcomes of your course justifying, your choice
6. Write the learning objectives of your course at different levels of Bloom's taxonomy

Adapted from Michael Prince's Workshop "*How to engineer engineering education*", July 2016

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Revised Bloom's Learning Taxonomy

The Knowledge Dimension classifies four types of knowledge that learners may be expected to acquire or construct—ranging from concrete to abstract (Table 1).

Table 1. The Knowledge Dimension – major types and subtypes

concrete knowledge → abstract knowledge			
factual	**conceptual**	**procedural**	**metacognitive***
knowledge of terminology knowledge of specific details and elements	knowledge of classifications and categories knowledge of principles and generalizations knowledge of theories, models, and structures	knowledge of subject-specific skills and algorithms knowledge of subject-specific techniques and methods knowledge of criteria for determining when to use appropriate procedures	strategic knowledge knowledge about cognitive tasks, including appropriate contextual and conditional knowledge self-knowledge

(Table 1 adapted from Anderson and Krathwohl, 2001, p. 46.)
*Metacognitive knowledge is a special case. In this model, "metacognitive knowledge is knowledge of [one's own] cognition and about oneself in relation to various subject matters . . . " (Anderson and Krathwohl, 2001, p. 44).

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http://www.celt.iastate.edu/wp-content/uploads/2015/09/RevisedBloomsHandout-1.pdf

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Revised Bloom's Learning Taxonomy

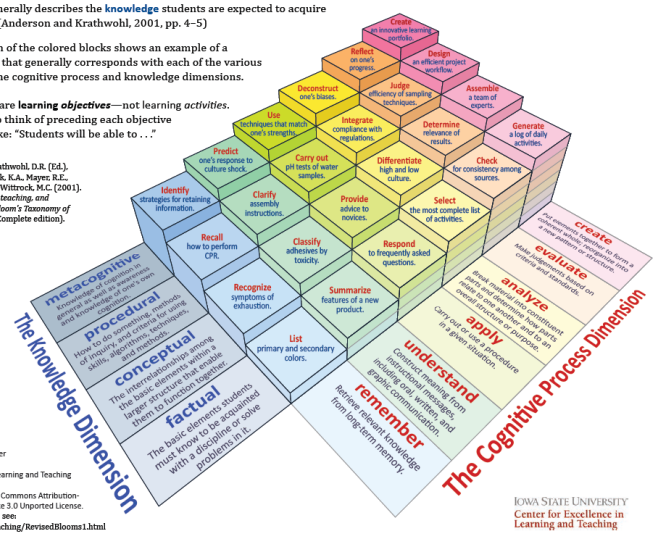
A statement of a **learning objective** contains a **verb** (an action) and an **object** (usually a noun).

- The **verb** generally refers to [actions associated with] the intended **cognitive process**.
- The **object** generally describes the **knowledge** students are expected to acquire or construct. (Anderson and Krathwohl, 2001, pp. 4–5)

In this model, each of the colored blocks shows an example of a learning objective that generally corresponds with each of the various combinations of the cognitive process and knowledge dimensions.

Remember: these are **learning *objectives***—not learning *activities*. It may be useful to think of preceding each objective with something like: "Students will be able to . . ."

*Anderson, L.W. (Ed.), Krathwohl, D.R. (Ed.), Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., Raths, J., & Wittrock, M.C. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives* (Complete edition). New York: Longman.



Model created by: Rex Heer
Iowa State University
Center for Excellence in Learning and Teaching
Updated January, 2012
Licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.
For additional resources, see:
www.celt.iastate.edu/teaching/RevisedBlooms1.html

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http://www.celt.iastate.edu/wp-content/uploads/2015/09/RevisedBloomsHandout-1.pdf

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Mapping Learning Objectives
Example from Ruth Wertz

Map of Week 5 Learning Objectives		Cognitive Process Dimension					
		1 Remember	2 Understand	3 Apply	4 Analyze	5 Evaluate	6 Create
Knowledge Dimension	A. Factual Knowledge	L2-GA					
	B. Conceptual Knowledge		L1-IK L3-IK				
	C. Procedural Knowledge						
	D. Metacognitive Knowledge			L4-EU L5-EU			

(Framework: Anderson & Krathwohl, 2001)

Content:

- [L1] Describe the meaning of the relationship between stress and strain.
- [L2] Define the modulus of elasticity, shear modulus, and Poisson's ratio
- [L3] Describe the physical meaning of effective stress.
- [L4] Compute total and effective vertical stresses under hydrostatic and seepage conditions.
- [L5] Estimate induced stresses at a discrete point or along a plane, due to an applied load.

Annotated Example: Map of Weekly Learning Objectives (Annotated Example).docx

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Mapping examples

- Classify different dynamic behaviors as the result of physicochemical interactions that can be modeled with computational tools. *Level 2 EO*
- Select the appropriate control parameters based on the character of the process, as seen through its response to known perturbations. *Level 4 ITK*
- Design and test controllers with the aid of computational tools. *Level 6 EO*

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Fink

TAXONOMY OF SIGNIFICANT LEARNING OUTCOMES

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Dee Fink – Creating Significant Learning Experiences

A TAXONOMY OF SIGNIFICANT LEARNING

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

4. Human Dimensions

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

5. Caring

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

6. Learning How to Learn

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

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Foundational Knowledge

What key information (e.g., facts, terms, formulae, concepts, principles, relationships, etc.) is/are important for students to understand and remember in the future?

What key ideas (or perspectives) are important for students to understand in this course?

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Application

What kinds of ***thinking*** are important for students to learn?

- **Critical thinking**, in which students analyze and evaluate
- **Creative thinking**, in which students imagine and create
- **Practical thinking,** in which students solve problems and make decisions

What important ***skills*** do students need to gain?

Do students need to learn how to ***manage complex projects***?

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Integration

What ***connections*** (similarities and interactions) should students recognize and make…:

- Among ideas *within* this course?
- Among the information, ideas, and perspectives in this course and those in other courses or areas?
- Among material in this course and the students' own personal, social, and/or work life?

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Human Dimension

What could or should students learn about ***themselves***?

What could or should students learn about ***understanding others*** and/or ***interacting with them***?

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Caring

What changes/values do you hope students will adopt?

- Feelings?
- Interests?
- Ideas?

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Learning-How-to-Learn

What would you like for students to learn about:

- **how to be good students** in a course like this?
- **how to learn about this particular subject**?
- **how to become a self-directed learner** of this subject, i.e., having a learning agenda of what they need/want to learn, and a *plan* for learning it?

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Application of Fink Taxonomy

Joi Mondisa - Developing Self-identity, Confidence, and Community: The NLFN STEM Girls' Mentoring Program Curricular Project

Taxonomy Level	Learning Objective
Foundational Knowledge	Recall at least three specific STEM career opportunities ….(LO6)
Integration	
Human Dimension	Describe two personal strengths (LO3)
Caring	
Learning how to Learn	Feel comfortable working together with others and constructing meaning with others (**LO5)**
Application	Create and engage in making a Legos robot in a robotic competition. (**LO7)**

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Learning Objectives and Taxonomies

Further Resources

- *What are learning objectives and how can we use them*? Appendix D of *How Learning Works* - http://firstliteracy.org/wp-content/uploads/2015/07/How-Learning-Works.pdf
- Two websites about (1) changes to Bloom's Taxonomy and (2) the revised Bloom's Taxonomy
  - https://thesecondprinciple.com/teaching-essentials/beyond-bloom-cognitive-taxonomy-revised/
  - http://www.celt.iastate.edu/wp-content/uploads/2015/09/RevisedBloomsHandout-1.pdf
  - http://www.celt.iastate.edu/teaching/effective-teaching-practices/revised-blooms-taxonomy/revised-blooms-taxonomy-flash-version
- Fink's Taxonomy – Self Directed Guide
  - https://www.deefinkandassociates.com/GuidetoCourseDesignAug05.pdf

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Activity: Taxonomy Discussion ~ 10 minutes

Please discuss the following questions with your small group:

1. Which taxonomy works better for your project? - Anderson and Krathwohl or Fink and why?
2. How do your learning objectives fit into the taxonomy you have selected?

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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 2 3 4 5 Too fast
5. Relevance: Little 1 2 3 4 5 Lots
6. Instructional Format: Ugh 1 2 3 4 5 Ah

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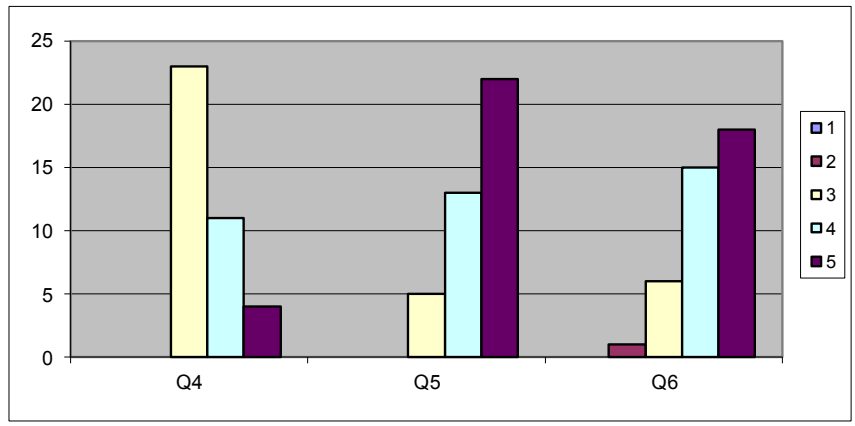
TEEW – Session 1 (5/22/18)



Q4 – Pace: Too slow 1 . . . . 5 Too fast (3.5)
Q5 – Relevance: Little 1 . . . 5 Lots (4.4)
Q6 – Format: Ugh 1 . . . 5 Ah (4.3)

Matching instruction to your curricular priorities

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Essential Questions

Are there useful ways to categorize different kinds of "active" or more student-centered teaching strategies?

How does one decide which kind of activity to use?

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Framework for looking at "active" learning

~~ACTIVE~~ ATTENTIONAL	CONSTRUCTIVE	INTERACTIVE
Doing something physically	Producing outputs that go beyond presented information	Dialoguing substantively on the same topic, and not ignoring a partner's contribution
Engaging activities	Self-construction	Guided-construction
Attending processes	Creation processes	Joint creation processes

ICAP framework, Michelene T.H. Chi

Chi, M.T.H. (2009). Active-Constructive-Interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*, 73-105

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Other papers about ICAP

Chi, M.T.H. & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49:4*, 219-243.

Menekse, M., Stump, G.S., Krause, S. & Chi, M.T.H. (2013). Differentiated overt learning activities for effective instruction in engineering classrooms. *Journal of Engineering Education*, *102*(3), 346-374.

Streveler, R.A. & Menekse, M. (2017). Guest editorial: Taking a closer look at active learning. *Journal of Engineering Education, 106* (2), 186-190.

"Attentional" strategies

Attention is the gateway to learning

However, many of us live in a state of continuous partial attention

Strategies to help your student pay attention are important.

Examples:

- Assigning observation roles while watching a live demonstration or video
- Asking students to repeat what another student has said
- Providing handouts with "fill in the blank" sections

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Constructive activities

Research on learning has shown that we learn new information by connecting new information to what we already know (this is called "Constructivism")

Constructive activities help your students make that bridge between new and previous knowledge

Examples:

- Providing an example of a concept or theory
- Explaining something in one's own words
- Converting written or numerical information into a diagram or graph

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Activity: Developing a constructive learning activity

Total Activity Time: ~15 minutes

Part 1: Individual Exercise (5 minutes)

Part 2: Small Group Discussion (10 minutes)

Part 3: Report out

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Activity Part I (5 Minutes): Sketch Plan

1. Describe your overall domain*
2. List an enduring outcome for your course*
3. List a Learning Objective (LO) associated with that enduring outcome*
4. **Create a constructive learning activity associated with that learning objective**

*You may refer to previous assignments for this information.

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Example

1. **Overall Domain:** Control Engineering for Chemical Engineers
2. **Enduring outcome:** Understanding the behavior of real processes as a consequence of their dynamic nature.
3. **LO:** Differentiate the building blocks of a complete process control loop and synthesize them to provide suitable process control solutions.
4. **Constructive activity:** Students will be given a conceptual model (printed diagram) of a process with two simple variables to control, namely temperature and level. They will be asked to predict the response of such variables to certain perturbations and select the perturbation with higher impact on the value of the variable.

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Activity Part II (10 Minutes)
Discuss with your Group

Share your plan. Discuss connections between your questions/activities and your objectives.

Activity Part III
Lightning Talk Report Out

Share the key takeaways from your small group discussion on your constructive learning activity plans. Were there any similarities amongst group members?

From Constructive Learning to Interactive Learning

Gaining students' attention and engaging them in constructive learning activities is more effective than when students are passive; however, it's not the best we know how to do.

Interactive learning is most effective and can bring about the highest learning gains.

However, interactive learning is also the most time-intensive (for instructors and learners). Use it when you need it most (with the most important and difficult concepts).

So… look at your curricular priorities. Those that are the most important (enduring outcomes and important to know) are worth the "investment" in constructive and interactive activities.

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Question: Your Experiences with Interactive Learning

What was your experience **as an undergraduate student** with interactive learning?

- First time you heard the term in a class setting *or* the first time you were asked to work with others in a class setting
- What did the instructor ask you to do?
- What rationale did the instructor provide?

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Karl's Experience

First Teaching Experience – Third-year course in metallurgical reactions – thermodynamics and kinetics

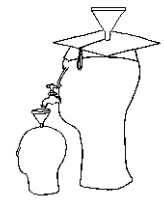
Lila M. Smith

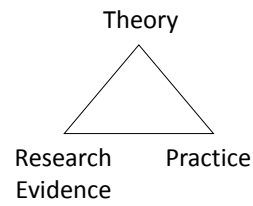
Karl's Quandary

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

Theory – ?

Research – ?





77

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
- Development Theories
- Motivation Theories
- Social psychology of learning – student – student interaction

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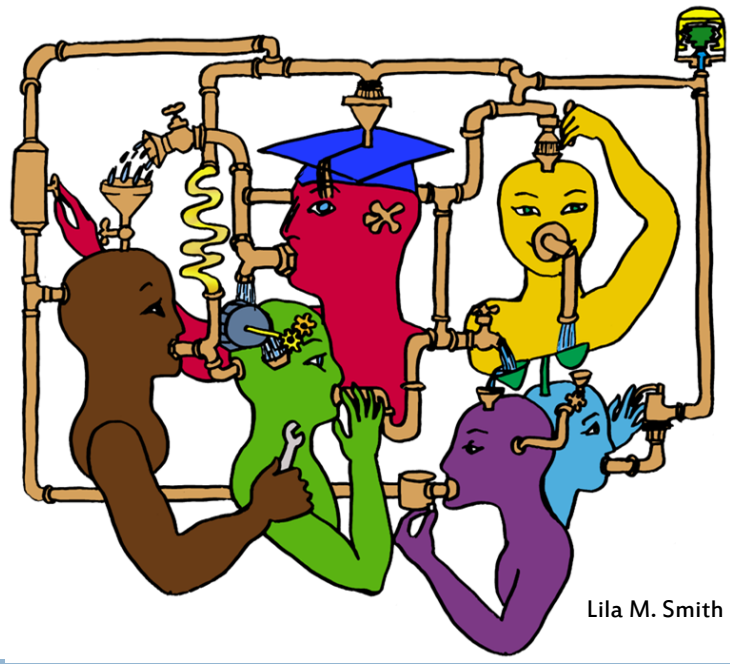

19

Cooperative Learning: An Evidence-Based Practice for Interactive Learning

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).

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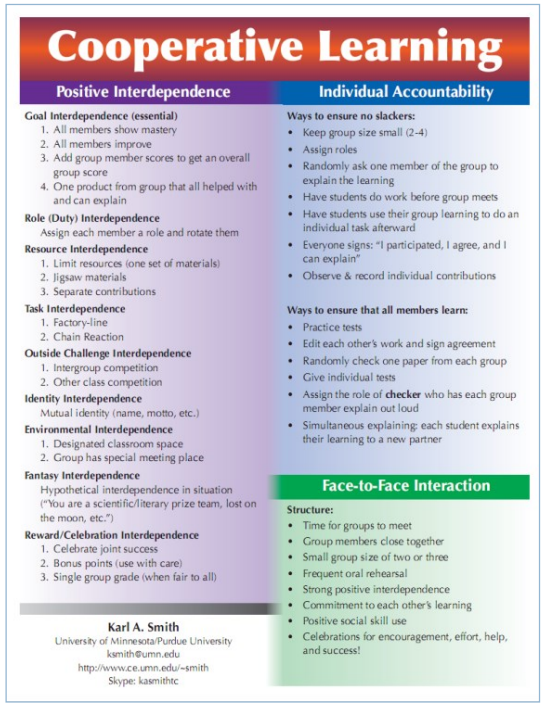

Cooperative Learning

Positive Interdependence

Goal Interdependence (essential)
1. All members show mastery
2. All members improve
3. Add group member scores to get an overall group score
4. One product from group that all helped with and can explain

Role (Duty) Interdependence
Assign each member a role and rotate them

Resource Interdependence
1. Limit resources (one set of materials)
2. Jigsaw materials
3. Separate contributions

Task Interdependence
1. Factory-line
2. Chain Reaction

Outside Challenge Interdependence
1. Intergroup competition
2. Other class competition

Identity Interdependence
Mutual identity (name, motto, etc.)

Environmental Interdependence
1. Designated classroom space
2. Group has special meeting place

Fantasy Interdependence
Hypothetical interdependence in situation ("You are a scientific/literary prize team, lost on the moon, etc.")

Reward/Celebration Interdependence
1. Celebrate joint success
2. Bonus points (use with care)
3. Single group grade (when fair to all)

Individual Accountability

Ways to ensure no slackers:
- Keep group size small (2-4)
- Assign roles
- Randomly ask one member of the group to explain the learning
- Have students do work before group meets
- Have students use their group learning to do an individual task afterward
- Everyone signs: "I participated, I agree, and I can explain"
- Observe & record individual contributions

Ways to ensure that all members learn:
- Practice tests
- Edit each other's work and sign agreement
- Randomly check one paper from each group
- Give individual tests
- Assign the role of **checker** who has each group member explain out loud
- Simultaneous explaining: each student explains their learning to a new partner

Face-to-Face Interaction

Structure:
- Time for groups to meet
- Group members close together
- Small group size of two or three
- Frequent oral rehearsal
- Strong positive interdependence
- Commitment to each other's learning
- Positive social skill use
- Celebrations for encouragement, effort, help, and success!

Karl A. Smith
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http://www.ce.umn.edu/~smith
Skype: kasmithtc

Key Concepts:

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

http://personal.cege.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.

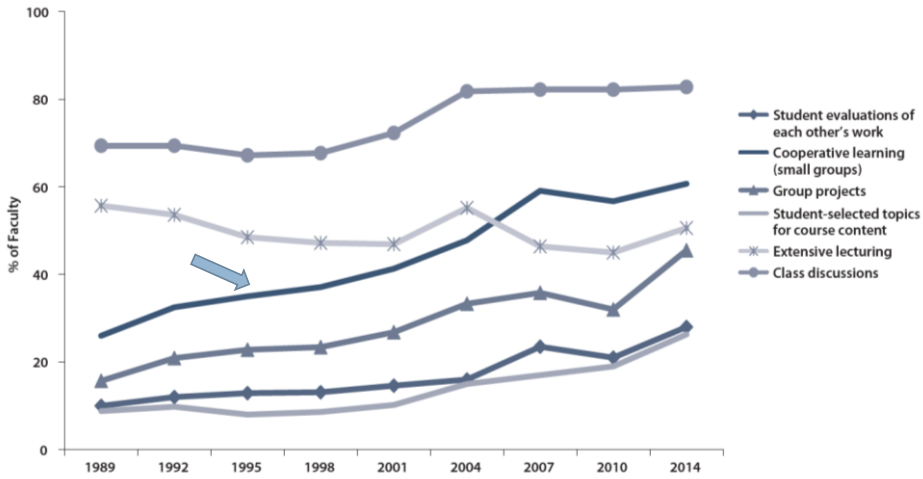
Structuring Learning Goals To Meet the Goals of Engineering Education

Karl A. Smith, David W. Johnson, and Roger T. Johnson
University of Minnesota

http://personal.cege.umn.edu/~smith/docs/Smith-Pedagogies_of_Engagement.pdf

Undergraduate Teaching Faculty: The 2013–2014 HERI Faculty Survey

Figure 2. Changes in Faculty Teaching Practices, 1989 to 2014
(% Marking "All" or "Most" Courses)



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http://heri.ucla.edu/monographs/HERI-FAC2014-monograph.pdf

Undergraduate Teaching Faculty, 2011*

Methods Used in "All" or "Most"	STEM women	STEM men	All other women	All other men
Cooperative learning	60%	41%	72%	53%
Group projects	36%	27%	38%	29%
Grading on a curve	17%	31%	10%	16%
Student inquiry	43%	33%	54%	47%
Extensive lecturing	50%	70%	29%	44%

*Undergraduate Teaching Faculty. National Norms for the 2010-2011 HERI Faculty Survey, www.heri.ucla.edu/index.php.

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Why Emphasize Cooperative Learning?

Student learning

Essential **transferrable skill** development

Key to **innovation**

High priority for **Employers**

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

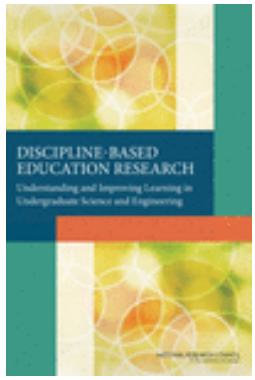
*[CLReturnstoCollege.pdf]

January 2005

March 2007

25 (3&4) 2014

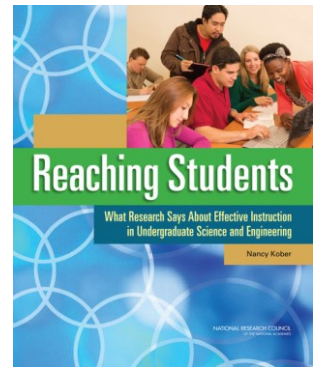
Discipline-Based Education Research (DBER) Report



National Research Council Summer 2012 – http://www.nap.edu/catalog.php?record_id=13362

ASEE *Prism Summer 2013*

Journal of Engineering Education – October 2013

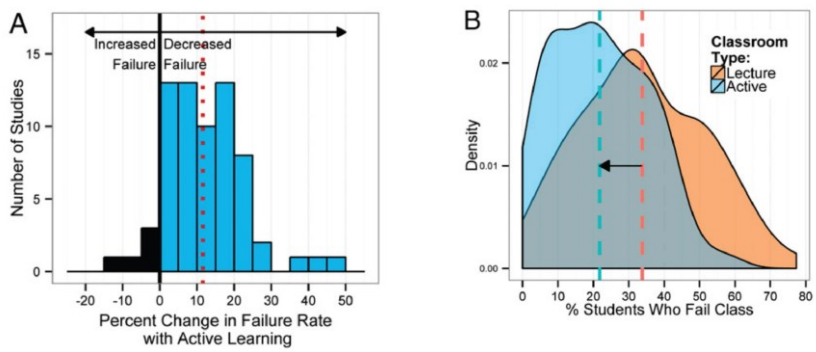


National Research Council – 2015 http://www.nap.edu/catalog/18687/reaching-students-what-research-says-about-effective-instruction-in-undergraduate

87

Engaged Pedagogies = Reduced Failure Rates

Evidence-based research on learning indicates that when students are actively involved in their education they are more successful and less likely to fail. A new PNAS report by Freeman et al., shows a significant decrease of failure rate in active learning classroom compared to traditional lecture



Freeman, Scott; Eddy, Sarah L.; McDonough, Miles; Smith, Michelle K.; Okoroafor, Nnadozie; Jordt, Hannah; Wenderoth, Mary Pat; Active learning increases student performance in science, engineering, and mathematics, 2014, Proc. Natl. Acad. Sci.

The College Degrees & Skills Employers Most Want in 2015 (National Association of Colleges & Employers (NACE))

The NACE survey also asked employers to rate **the skills they most value in new hires**. Companies want candidates who can think critically, solve problems, work in a team, maintain a professional demeanor and demonstrate a strong work ethic. Here is the ranking in order of importance:

Competency	Essential Need Rating*
Critical Thinking/Problem Solving	4.7
Teamwork	4.6
Professionalism/Work Ethic	4.5
Oral/Written Communications	4.4
Information Technology Application	3.9
Leadership	3.9
Career Management	3.6

*Weighted average. Based on a 5-point scale where 1=Not essential, 2=Not very essential; 3=Somewhat essential; 4=Essential; 5=Absolutely essential

http://www.forbes.com/sites/susanadams/2015/04/15/the-college-degrees-and-skills-employers-most-want-in-2015/

Observational study of over 2000 classes – most common behaviors:

- Faculty
  - Lecturing
  - Writing in real time
  - Posing nonrhetorical questions
  - Following-up on questions
  - Answering student questions
  - Clicker questions
- Students
  - Listening to instructor
  - Answering instructor questions
  - Asking questions

http://science.sciencemag.org/content/sci/359/6383/1468.full.pdf

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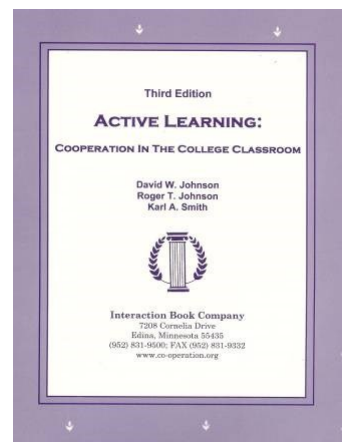
Pedagogies of Engagement

Cooperation in the College Classroom

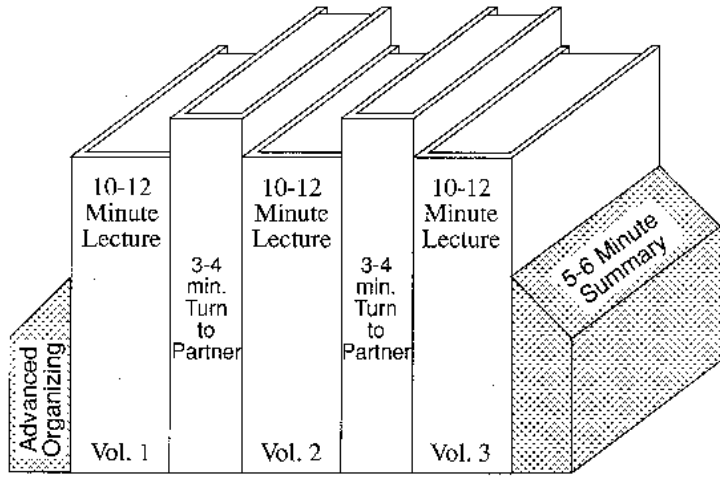
- **Informal** Cooperative Learning Groups
- **Formal** Cooperative Learning Groups
- Cooperative **Base** Groups

Notes: Cooperative Learning Handout (CL-College-814.doc) [CL-College-814.doc]



First edition 1991.

Book Ends on a Class Session



Smith, K.A. 2000. Going deeper: Formal small-group learning in large classes. Energizing large classes: From small groups to learning communities. *New Directions for Teaching and Learning*, 2000, 81, 25-46. [NDTL81Ch3GoingDeeper.pdf]

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Book Ends on a Class Session

1. Advance Organizer
2. Formulate-Share-Listen-Create (Turn-to-partner) — *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?

1 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.

95

2 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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2 Focus Question Examples

- Give an example
- Describe an application…
- Explain in your own words…
- Paraphrase the idea
- Support the following statement…

97

Activity: Developing a "Book Ends on a Class Session" Plan

Total Activity Time: ~20 minutes

Part 1: Individual Exercise (5 minutes)

Part 2: Small Group Discussion (15 minutes)

Part 3: Lightning Talk Report Out

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Informal Cooperative Learning Planning Form

Description of the Class Session: _____

1. **Your Name, Department, and Course Title:** _____
2. **Session Topic:** _____
3. **Objectives** (Major Understandings Students Need to Have At The End Of The Session):
   a. _____
   b. _____
4. **List the Enduring or Important to Know Outcome that this activity is targeting.**
   _____
5. **Time Needed:** _____
6. **Method for Assigning Students to Pairs Or Triads:** _____
7. **Method for Changing Partners Quickly:** _____
8. **Materials** (such as slides or handouts listing the questions to be discussed and describing the **formulate, share, listen, create** procedure):
   _____

Advanced Organizer Question(s)

Questions should be aimed at promoting **advance organizing** of what the students know about the topic to be presented and **establishing expectations** as to what the session will address.

1. _____
2. _____
3. _____

1

Cognitive Rehearsal Questions

List the specific questions to be asked every 10 or 15 minutes to ensure that participants understand and process the information being presented. Instruct students to use the **formulate, share, listen, and create** procedure.

1. _____
2. _____
3. _____
4. _____

Monitor by systematically observing each pair. Intervene when it is necessary. Collect data for whole class processing. Students' explanations to each other provide a window into their minds that allows you to see what they do and do not understand. Monitoring also provides an opportunity for you to get to know your students better.

Summary Question(s)

Give an ending discussion task and require students to come to consensus, write down the pair or triad's answer(s), sign the paper, and hand it in. Signatures indicate that students agree with the answer, can explain it, and guarantee that their partner(s) can explain it. The questions could (a) ask for a summary, elaboration, or extension of the material presented or (b) precue the next class session.

1. _____
2. _____

Celebrate Students' Hard Work

Provide a close to the activity by asking students to acknowledge their partner, for example by (1) thanking them or (2) mentioning one thing their partner did that helped them learn.

1. _____
2. _____

2

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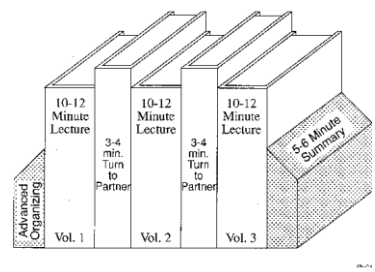
Activity Part I (5 Minutes) Sketch Plan

1. List Session Topic*
2. Learning Objective (for an Enduring Outcome)*
3. List Activity*
4. **Write 2 – 4 "focus" questions.**



*Use the same information here as you did for the first activity of today's session.

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Activity Part II (10 Minutes) Discuss with your Group

Share your plan and focus questions with your group.

Activity Part III - Lightning Talk Report Out

Share the key takeaways from your small group discussion on your plans. Were there any similarities with plans or questions?

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 and one-time events (e.g., guest presentation)
- Include "book ends" procedure
- Are not as effective as Formal Cooperative Learning or Cooperative Base Groups

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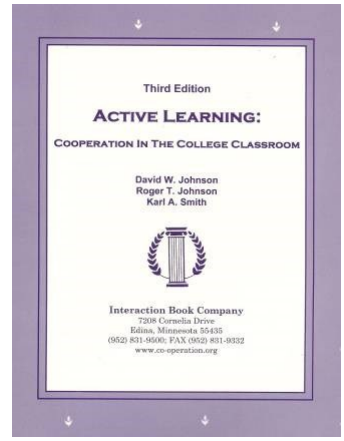
Active Learning: Cooperation in the College Classroom

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

Notes: Cooperative Learning Handout (CL-College-814.doc)
[CL-College-814.doc]



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Instructor's Role in Formal Cooperative Learning

1. Specifying **Objectives** (Academic and Interpersonal/Teamwork)
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

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Cooperative Problem-Based Learning Format

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

INDIVIDUAL: Develop ideas, Initial Model, Estimate, etc. 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 model and 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.

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Decisions, Decisions…

- Group size?
- Group selection?
- Group member roles?
- How long to leave groups together?
- Arranging the room?
- Providing materials?
- Time allocation?

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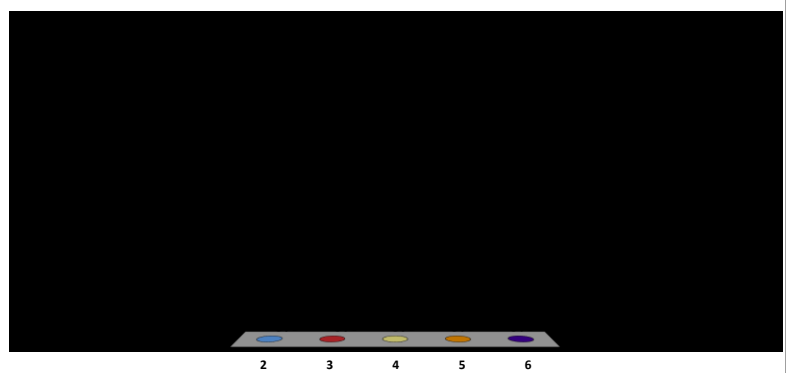
Optimal Group Size?

A. 2
B. 3
C. 4
D. 5
E. 6



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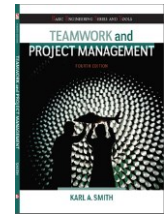
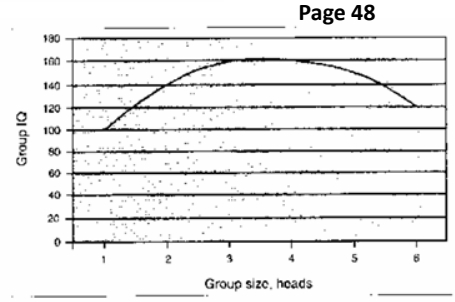
Formal Cooperative Learning Task Groups



Page 48

Perkins, David. 2003. *King Arthur's Round Table: How collaborative conversations create smart organizations.* NY: Wiley.



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Group Selection?

A. Self selection
B. Random selection
C. Stratified random
D. Instructor assign
E. Other

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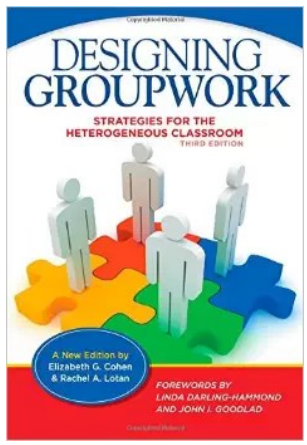
Assigning Roles



Chapter 8: Group Roles and Responsibilities

- Roles
  - Facilitator
  - Checker
  - Set-Up
  - Materials Manager
  - Safety Officer
  - Reporter
- Dividing the labor

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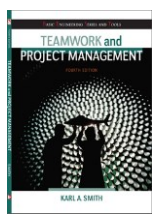
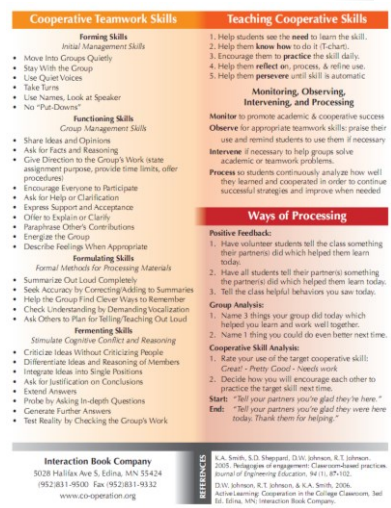
Teamwork Skills

- Communication
  - Listening and Persuading
- Decision Making
- Conflict Management
- Leadership
- Trust and Loyalty



Chapters 3, **4**, 5 & 6



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TEAMWORK

Teaching Cooperative Skills

1. Help students see the **need** to learn the skill.
2. Help them **know how** to do it (T-chart).
3. Encourage them to **practice** the skill daily.
4. Help them **reflect o**n, process, & refine use.
5. Help them **persevere** until skill is automatic

Monitoring, Observing, Intervening, and Processing

Monitor to promote academic & cooperative success

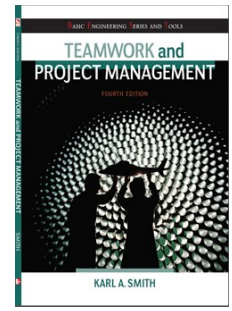
Observe for appropriate teamwork skills: praise their use and remind students to use them if necessary

Intervene if necessary to help groups solve academic or teamwork problems.

Process so students continuously analyze how well they learned and cooperated in order to continue successful strategies and improve when needed

Team Charter

- Team name, membership, and roles
- Team mission
- Anticipated results (goal)
- Specific tactical objectives
- **Ground rules/ Guiding principles for team participation**
- Shared expectations/aspirations



pp. 60-61, 204-205

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Group Ground Rules Contract Form
(Adapted from a form developed by Dr. Deborah Allen, University of Delaware)

Project groups are an effective aid to learning, but to work best they require that all groups members clearly understand their responsibilities to one another. These project group ground rules describe the general responsibilities of every member to the group. You can adopt additional ground rules if your group believes they are needed. Your signature on this contract form signifies your commitment to adhere to these rules and expectations.

All group members agree to:

1. Come to class and team meetings on time.
2. Come to class and team meetings with assignments and other necessary preparations done.

Additional ground rules:

1.

2.

If a member of the project team repeatedly fails to meet these ground rules, other members of the group are expected to take the following actions:

Step 1: (fill in this step with your group)

If not resolved:
Step 2: Bring the issue to the attention of the teaching team.
If not resolved:
Step 3: Meet as a group with the teaching team.

The teaching team reserves the right to make the final decisions to resolve difficulties that arise within the groups. Before this becomes necessary, the team should try to find a fair and equitable solution to the problem.

Member's Signatures: Group Number:_____

1._____ 3._____

2._____ 4._____

The Instructor's Role in Cooperative Learning

Make Pre-Instructional Decisions

Specify Academic and Teamwork Skills Objectives: Every lesson has both (a) academic and (b) interpersonal and small group (teamwork) skills objectives.

Decide on Group Size: Learning groups should be small (groups of two or three members, four at the most).

Decide on Group Composition (Assign Students to Groups): Assign students to groups randomly or select groups yourself. Usually you will wish to maximize the heterogeneity in each group.

Assign Roles: Structure student-student interaction by assigning roles such as Reader, Recorder, Encourager of Participation and Checker for Understanding.

Arrange the Room: Group members should be "knee to knee and eye to eye" but arranged so they all can see the instructor at the front of the room.

Plan Materials: Arrange materials to give a "sink or swim together" message. Give only one paper to the group or give each member part of the material to be learned.

Explain Task And Cooperative Structure

Explain the Academic Task: Explain the task, the objectives of the lesson, the concepts and principles students need to know to complete the assignment and the procedures they are to follow.

Explain the Criteria for Success: Student work should be evaluated on a criteria-referenced basis. Make clear your criteria for evaluating students' work.

***Structure Positive Interdependence**: Students must believe they "sink or swim together." Always establish mutual goals (students are responsible for their own learning and the learning of all other group members). Supplement, goal interdependence with celebration/reward, resource, role, and identity interdependence.

Structure Intergroup Cooperation: Have groups check with and help other groups. Extend the benefits of cooperation to the whole class.

***Structure Individual Accountability**: Each student must feel responsible for doing his or her share of the work and helping the other group members. Ways to ensure accountability are frequent oral quizzes of group members picked at random, individual tests, and assigning a member the role of Checker for Understanding.

***Specify Expected Behaviors**: The more specific you are about the behaviors you want to see in the groups, the more likely students will do them. Social skills may be classified as **forming** (staying with the group, using quiet voices), **functioning** (contributing, encouraging others to participate), **formulating** (summarizing, elaborating), and **fermenting** (criticizing ideas, asking for justification). Regularly teach the interpersonal and small group skills you wish to see used in the learning groups.

Monitor and Intervene

***Arrange Face-to-Face Promotive Interaction**: Conduct the lesson in ways that ensure that students promote each other's success face-to-face.

Monitor Students' Behavior: This is the fun part! While students are working, you circulate to see whether they understand the assignment and the material, give immediate feedback and reinforcement, and praise good use of group skills. Collect observation data on each group and student.

Intervene to Improve Taskwork and Teamwork: Provide **taskwork assistance** (clarify, reteach) if students do not understand the assignment. Provide **teamwork assistance** if students are having difficulties in working together productively.

Evaluate and Process

Evaluate Student Learning: Assess and evaluate the quality and quantity of student learning. Involve students in the assessment process.

***Process Group Functioning**: Ensure each student receives feedback, analyzes the data on group functioning, sets an improvement goal, and participates in a team celebration. Have groups routinely list three things they did well in working together and one thing they will do better tomorrow. Summarize as a whole class. Have groups celebrate their success and hard work.

Cooperative Lesson Planning Form

Subject Area: _____ Date: _____

Lesson: _____

Objectives

Academic: _____

Social Skills: _____

Preinstructional Decisions

Group Size: _____ Method Of Assigning Students: _____

Roles: _____

Room Arrangement: _____

Materials: _____

- ◊ One Copy Per Group
- ◊ One Copy Per Person
- ◊ Jigsaw
- ◊ Tournament
- ◊ Other: _____

Explain Task And Cooperative Goal Structure

1. Task: _____
2. Criteria For Success: _____
3. Positive Interdependence: _____
4. Individual Accountability: _____
5. Intergroup Cooperation: _____
6. Expected Behaviors: _____

Monitoring And Intervening

1. Observation Procedure: _____ Formal _____ Informal
2. Observation By: _____ Teacher _____ Students _____ Visitors
3. Intervening For Task Assistance: _____
4. Intervening For Teamwork Assistance: _____
5. Other: _____

Evaluating And Processing

1. Assessment Of Members' Individual Learning: _____
2. Assessment Of Group Productivity: _____
3. Small Group Processing: _____
4. Whole Class Processing: _____
5. Charts And Graphs Used: _____
6. Positive Feedback To Each Student: _____
7. Goal Setting For Improvement: _____
8. Celebration: _____
9. Other: _____

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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

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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 2 3 4 5 Too fast
5. Relevance: Little 1 2 3 4 5 Lots
6. Instructional Format: Ugh 1 2 3 4 5 Ah