Principles for Classroom and Curricular Innovation

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"There is an incredible evolution of learning or education as almost the sole source of competitive advantage in an economy that has changed so much."

Howard Block, Managing Director

Banc of America Securities

An investment-bank and brokerage subsidiary of Bank of America.

Challenges in Engineering Education

- **Challenges**
  - Challenge of lifelong learning
  - Challenge of problem solving
  - Challenge of engineering design
  - Challenge of transfer

LASSI SCALE	ENGR111 (Mean)	CVEN349 (Mean)	Significance*
Skill Component			
Information Processing	60.68	60.29	0.930
Test Strategies	64.33	63.27	0.794
Selecting Main Ideas	55.18	59.29	0.342
Will Component			
Anxiety	60.52	67.12	0.147
Attitude	42.47	34.56	0.080
Motivation	63.30	59.29	0.397
Self-regulation Component			
Concentration	61.31	54.56	0.144
Self-testing	52.47	37.92	0.006
Study Aids	60.24	45.04	0.005
Time Management	55.23	47.65	0.134

Challenge of Problem Solving

"Despite individual professors' dedication and efforts to develop problem solving skill, "general problem solving skill" was not developed in the four years in our undergraduate program. Students graduated showing the same inability that they had when they started the program. Some could not create hypotheses; some misread problem statements. During the four-year undergraduate engineering program studied, 1974-1978, the students had worked over 3000 homework problems, they had observed about 1000 sample solutions being worked on the board by either the teacher or by peers, and they had worked many open-ended problems. In other words, they showed no improvement in problem solving skills despite the best intentions of their instructors."

Woods, D. et al (1997) "Developing Problem Solving Skills: The McMaster Problem Solving Program," Journal of Engineering Education,

Challenge of Problem Solving

- **Ineffective approach #1. give the students open-ended problems to solve; *This, we now see, is ineffective because the students get little feedback about the process steps, they tend to reinforce bad habits, they do not know what processes they should be using and they resort to trying to collect sample solutions and match past memorized sample solutions to new problem situations.***

Challenge of Problem Solving

- **Ineffective approach # 2:** **Show them how you solve problems by working many problems on the board and handing out many sample solutions**
  - *This, we now see, is ineffective because teachers know too much. Teachers demonstrate "exercise solving". Teachers do not make mistakes; they do not struggle to figure out what the problem really is. They work forwards; not backwards from the goal. They do not demonstrate the "problem solving" process; they demonstrate the "exercise solving" process. If they did demonstrate "problem solving" with all its mistakes and trials, the students would brand the teacher as incompetent. We know; we tried!*

Challenge of Problem Solving

- **Ineffective approach #3:** **Have students solve problems on the board**
  - *Different students use different approaches to solving problems; what works for one won't work for others. When we used this method as a research tool, the students reported "we learned nothing to help us solve problems by watching Jim, Sue and Brad solve those problems!"*

Challenge of Problem Solving

- **Through four research projects we identified why and how these and other teaching methods failed to develop process skills and which methods were successful in developing the skills**

- Woods, D.R., J.D. Wright, T.W. Hoffman, R.K. Swartman and I.D. Doig (1975) "Teaching Problem Solving Skills," Annals of Engineering Education, 1, 1, 238-243.
- Woods, D.R. et al. (1979) "Major Challenges to Teaching Problem Solving" Annals of Engineering Education, 70, No. 3 p. 277 to 284, 1979 and "56 Challenges to Teaching Problem Solving" CHEM 13 News no. 155 (1985).
- Woods, D.R. (1993a) "Problem solving - where are we now?" J. College Science Teaching, 22, 312-314.
- Woods, D.R. (1993b) "Problem solving - what doesn't seem to work," J. College Science Teaching, 23, 57-58.
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Challenge of Engineering Design

The literature is filled with positive comments from students, instructors, and industrial sponsors who have participated in capstone design courses. The vast majority of participants feel that the course benefited all involved.

The nature of capstone design courses, however, often leads to a **purely subjective evaluation with little or no "hard evidence" of actual benefits**. Born, for example, does not attempt to prove the value of senior level design courses. He simply states that he is convinced from his experiences that such courses are valuable. Other educators have similar "feelings" as to the relative costs and benefits of capstone design courses.

Dutson, A.J., Todd, R.H., Magleby, S.P., Sorensen, C.D., (1997) "A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses." *Journal of Engineering Education*

Challenge of Transfer

Researches posed this problem to people.

"Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the health tissue?"

Challenge of Transfer

Consider the following story

"A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned that the dictator had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the dictator need to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress. However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group continued down it road to the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator."

Challenge of Transfer

- After the subjects read and summarized this story, they were asked to solve the tumor problem under the guise of a separate experiment.
- Given the clear analogy, you might think that performance would be near ceiling. Surprisingly, only 30% of the subjects offered a convergence solution.
- Moreover, when these same subjects were given the suggestion that they should use the General story, 80% provided a convergence solution.
- This finding demonstrates that half the subjects could apply the General story to the tumor problem when they were instructed to but did not do so on their own.

Focusing Activity (8 minutes)

- **INDIVIDUALLY** – use 3 minutes to write your description of learning, what it is, what it looks like, how you might recognize when it has occurred, etc.
- **AS A PAIR** – use 5 minutes to discuss descriptions with someone sitting next to you. If you have additional time, develop a consensus description of learning.

Focusing Activity

- Different ways to describe the same thing
- Supported by partner
- Learning is a process, highly mental, key to creativity and using our experience
- Learning and knowledge is applied, specifically and the usefulness of what was learned
- Learning is process of acquiring of knowledge and skills and there are different levels
- Started with process of acquiring basic level skills and understanding the processes and using knowledge and skills to solve problems
- Relationsihip between seeing big picture and incremental skills, transferring between the two
- We have a narrow perspective based on similar backgrounds
- Satisfaction with life, learning can be satisfying
- Approach as problem solving, partner brought in survival, lifelong learning (different perspectives)
- More than just engineering learning
- Different: general approach vs. more detailed approach

Model for Learning and Teaching

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Pedagogical Approaches

- **Active Learning**
- **Cooperative Learning**
- **Problem-Based Learning**
- **Project-Based Learning**
- **Discovery Learning**
- **Inquiry-Based Learning**
- **Case-Based Learning**

Possible Confusion

"A common misconception regarding 'constructivist' theories of knowing (that existing knowledge is used to build new knowledge) is that teachers should never tell students anything directly but, instead, should always allow them to construct knowledge for themselves. **This perspective confuses a theory of pedagogy (teaching) with a theory of knowing**. Constructivists assume that knowledge is constructed from previous knowledge, irrespective of how one is taught -- even listening to a lecture involves active attempts to construct new knowledge… Nevertheless, there are times, usually after people have first grappled with issues on their own, that 'teaching by telling' can work extremely well."

How People Learn, Bransford, John D. et. al. 1999

Four Fundamental Questions

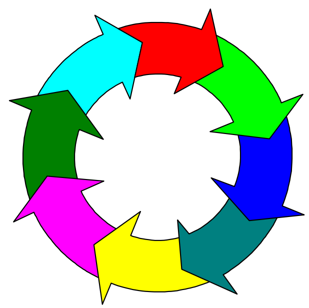
- What do I want people to learn?
- Where are learners starting from?
- How do people learn?
- How might I facilitate learning?

Expectations and Assessment

What do you want people to learn?

Learning Theories

How do people learn?



Pedagogical Theories

How do you facilitate learning?

Current Reality

What are learners starting from?

Expectations and Assessment

What do you want people to learn?

- Course syllabi
- Learning objectives
- Taxonomies, e.g., Bloom's Taxonomy, …
- Competency matrices
- Rubrics

Expectations and Assessment

What do you want people to learn?

Current Reality

Where are learners starting from?

- Existing knowledge, strategies, beliefs, etc.
  - Experience with past students
- Data about entering students
- Self-assessment
- Pre-tests (placement tests, SPQ, LASSI, etc.)

Expectations and Assessment

What do you want people to learn?

How do people learn?

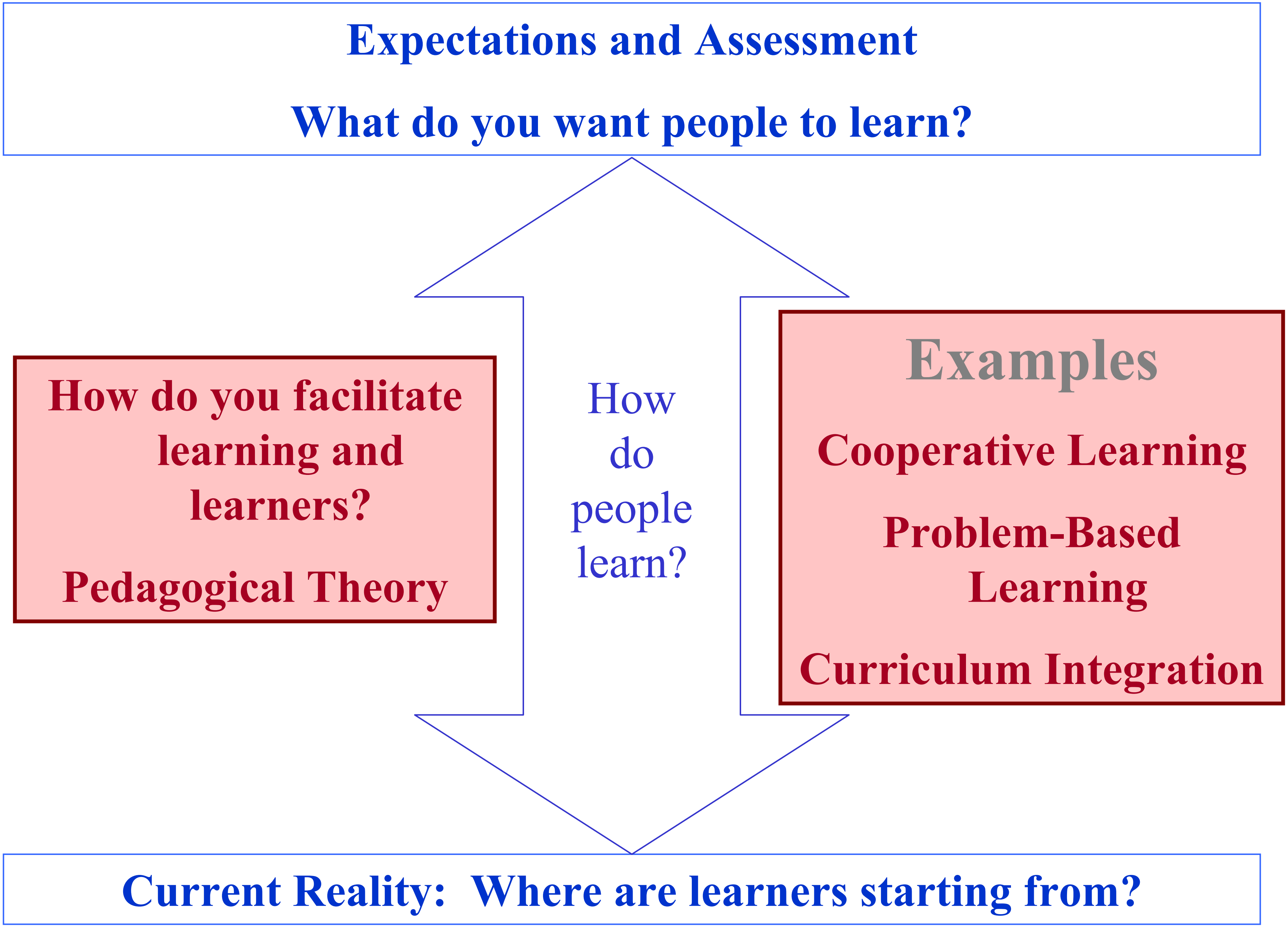
How do people close the gap?

Behaviorist

Cognitive

Metacognitive

Current Reality: Where are learners starting from?


Expectations and Assessment
What do you want people to learn?
How do you facilitate learning and learners?
Pedagogical Theory
How do people learn?
Examples
Cooperative Learning
Problem-Based Learning
Curriculum Integration
Current Reality: Where are learners starting from?

Four Questions

- **What do I want people to learn?**
  - Expectations, judgment
- **Where are learners starting from?**
  - Data, experience
- **How do people learn?**
  - Learning processes, learning theory
  - Research: neurology, psychology, cognitive science, artificial intelligence, physics education
- **How might I facilitate learning?**
  - Teaching processes, pedagogical theory

Assessment Tetrahedron

- **What do I want people to learn?**
  - Expectations, judgment
- **How do people learn?**
  - Learning processes, learning theory
  - Research: neurology, psychology, cognitive science, artificial intelligence, physics education
- **How might I acquire data about learning?**
  - Measurement theory
- **How might I interpret data about learning?**
  - Statistics, modeling

Deciding Where To Go

- Individually
- If this were a successful workshop, describe what you would have learned and/or what skills you would have at the conclusion of the workshop that you did not have at the beginning.
- Be specific and list lots of things.
- Take about 3 minutes

Deciding Where To Go

- Form teams of four.
- Take the four lists and merge to a single list of 4-5 items on which you have consensus.
- Take about 5 minutes

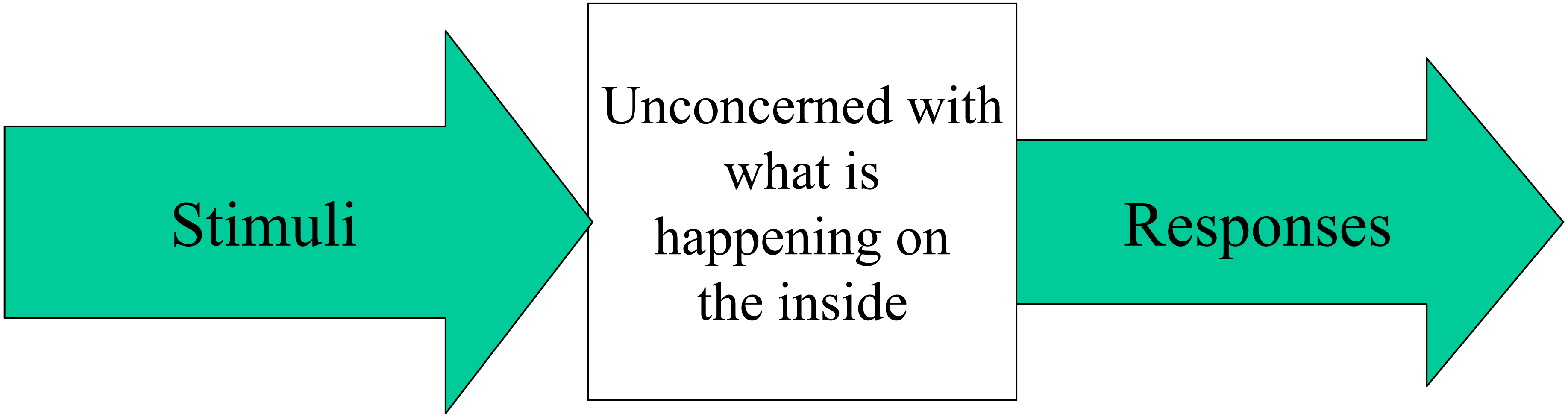
Deciding Where To Go

- ??

Evolution of Streams of Learning

- **Stream 1: Behaviorist Stream**
- **Stream 2: Cognitive (Information Processing) Stream**
- **Stream 3: Metacognitive Stream**

Behaviorist



Behaviorist

- **Learning as conditioning**
- **Classical conditioning**
  - Pavlov’s dogs
- **Operant conditioning**
  - Training dogs with a reward, eventually the reward is no longer needed

Behaviorist

- **Learning as associations among stimuli and responses**
- **Instructional implications**
  - Specify outcomes in clear, observable terms known as instructional objectives
  - Divide the target behaviors into small, easy-to-achieve steps and present in a logical sequence
  - Use mastery as the criterion for progress

Why might a behaviorist model be inadequate?

- **“Is it going to be on the test?”**
  - Learning to the test
  - Teaching to the test
  - Performance focus instead of mastery focus
- **“Didn’t you learn this in the prerequisite class?”**
  - Remembering words: fMRI studies
  - Linkages: remembering people’s names
  - Qualitative study at Berkeley
  - Gender differences in approaches to problem solving
- **“Can you envision a behaviorist learning environment that responds to the four challenges?”**

Recalling Words/Images

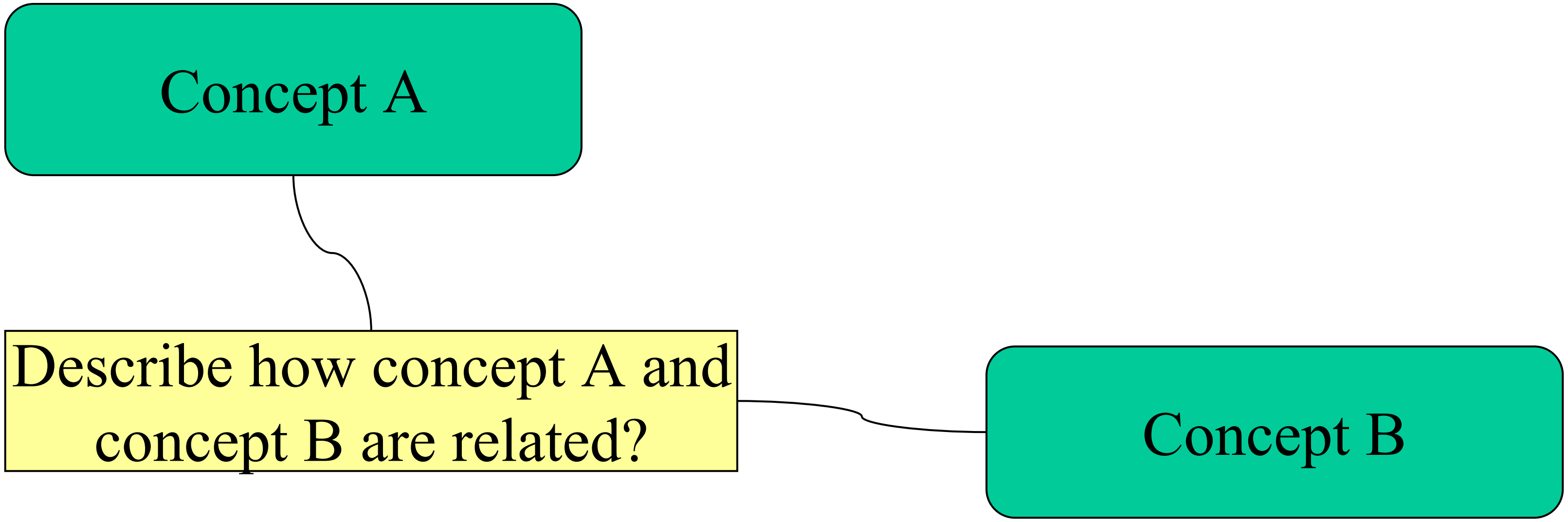
- **fMRI studies can show what part(s) of the brain are active during a particular task.**
- **Place subjects in fMRI tunnel and show them a list of words (images).**
- **Can you predict from the fMRI scan taken during the presentation of a word (image) whether a subject will recall the word (image)? Yes!**
- **Activity in two regions is important.**
  - One region is in the inner part of the temporal lobe: the parahippocampal gyrus in the left (right) cerebral hemisphere.
  - The other region is in the lower left (right) part of the frontal lobes, where apparently links are being made to existing information.

Recalling Names

- **Have you ever been talking to someone and said, "Someone was telling me about X and her name is …….. I can't remember."**
- **However, you can remember what the person looked like, where she lives, her occupation, etc.**
- **If you imagine a giant concept map within the brain, it appears that names (or other proper names) are often weakly connected to other concepts as opposed to common nouns.**
- **Without intention, instruction on a new concept may create a map in which the concept is weakly connected to other ideas.**

Concept Map

- A concept map is a set of nodes that represent concepts connected by a labeled links that describe a link between concepts.



Team Exercise
Building a Concept Map

- **Start with a subset of the concepts on the following page and construct a concept map that shows the concepts you have selected and how they are related.**
- **Exchange concept maps and share insights**

Feedback
Derivative
Finite Element Analysis
Integral
Linear Momentum
Angular Momentum
Energy
Interest
Mass
Ideal Gas Law
Fick's First Law
Fick's Second Law
Vectors: Dot Product
Vectors: Cross Product
Ordinary Differential Equations
Kirchoff's Voltage Law
Second Law of Thermodynamics
Kirchoff's Current Law
Modeling
Problem-Solving
Force
Ohm's Law
Resistance
Complex Numbers
Logarithmic Function
Electric Flux
Decision Theory
Divergence
Indirect Cost
Capacitance
Bending Moment
Feedback

First Law of Thermodynamics
Entropy
Heat
Electric Field
Magnetic Field
Partial Differential Equations
Determinants
Return on Investment
Phasors
Brainstorming
Exponential Function
Conductivity
Chemical Kinetics
Specific Heat
Elasticity
Malleability
Plasticity
Resiliency
Permittivity
Current
Electric Potential
Curl
Presentation Skills
Democracy
Profit
Density
Molecule
Phase
Shear
Rheology
Frequency Response
Eigenvalue, Eigenvector

Sinusoidal Functions
Work
Displacement
Velocity
Acceleration
Resistivity
Leadership
Hess' Law
Zeroth Law of Thermodynamics
Electric Potential
Magnetic Flux
Design
Maxwell's Equations
Power
Ductility
Spring Constant
Stress
Strain
Partial Derivative
Permeability
Charge
Magnetic Potential
Gradient
Paragraph
Rate of Return
Frequency
Atom
Root Locus
Torque
Inductance
Torsion
Polymer
Kinetic Theory of Gases

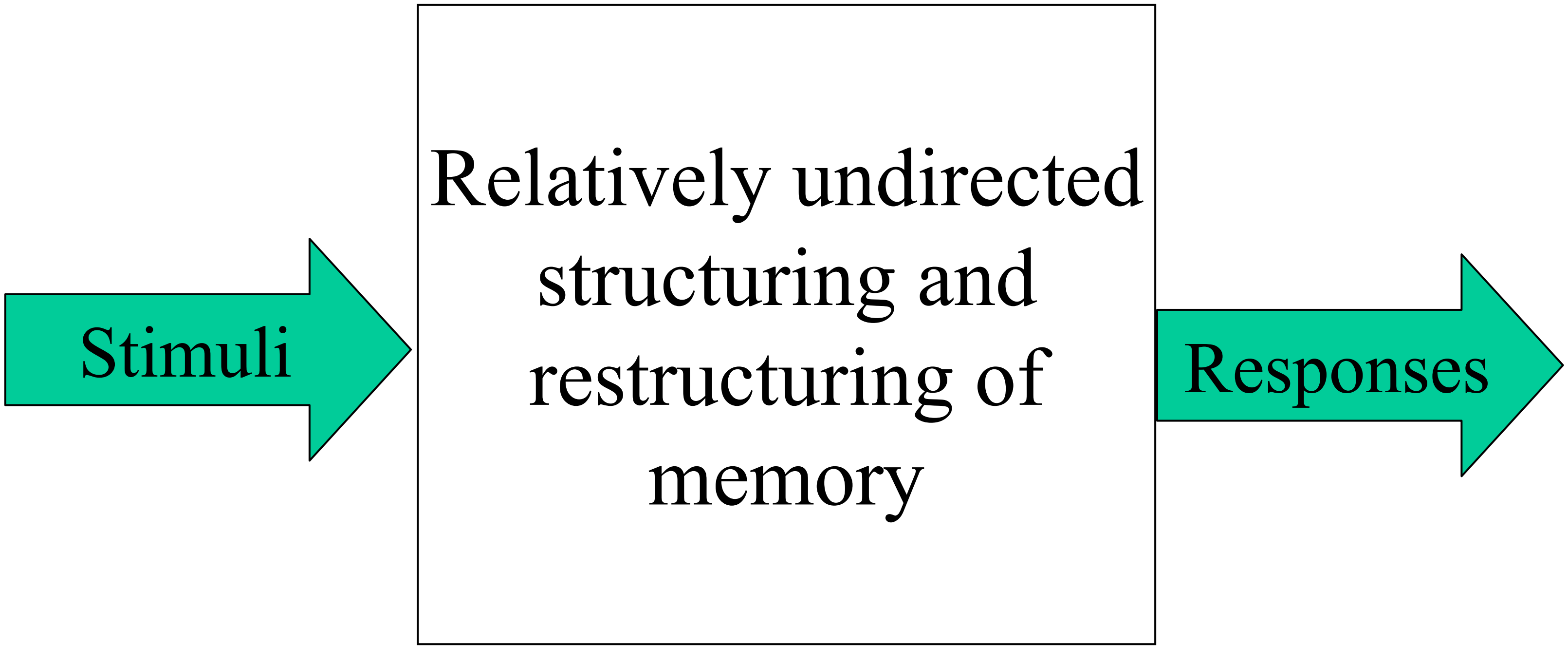
Student Perspective

- **Researchers at the University of California Berkeley interviewed about 70 mechanical engineering students about their learning experiences in college.**
- **Although the researchers were aware of various integrated curricula that had been implemented across the country, they were interested in the student perspective of integration, as well as the pedagogical perspective.**
- **Data from the interviews tended to support the value of linking concepts. For example, "Of the 70 students interviewed, 60% commented on the benefit of linking concepts across disciplines."**

Gender Differences

- Rosser and Sandler both report a difference between how men and women approach problems.
- Men tend to handle problems with a single correct or concrete answer comfortably
- Women are better able to deal with complex problems and problems that are ambiguous.
- Rosser asserts that many of the first year courses are more directed to single correct or concrete answers, which favor the learning style of men. This is one of the reasons, she believes, that women with high GPAs may leave the major in the first year.

Cognitive, Information Processing



Cognitive, Information Processing

- **Learning as information processing**
- **Elements**
  - Memory: short-term and long-term
  - Processing
  - Executive
- **Questions**
  - How does the learner encode new information?
  - How does the learner organize, represent, and link information?

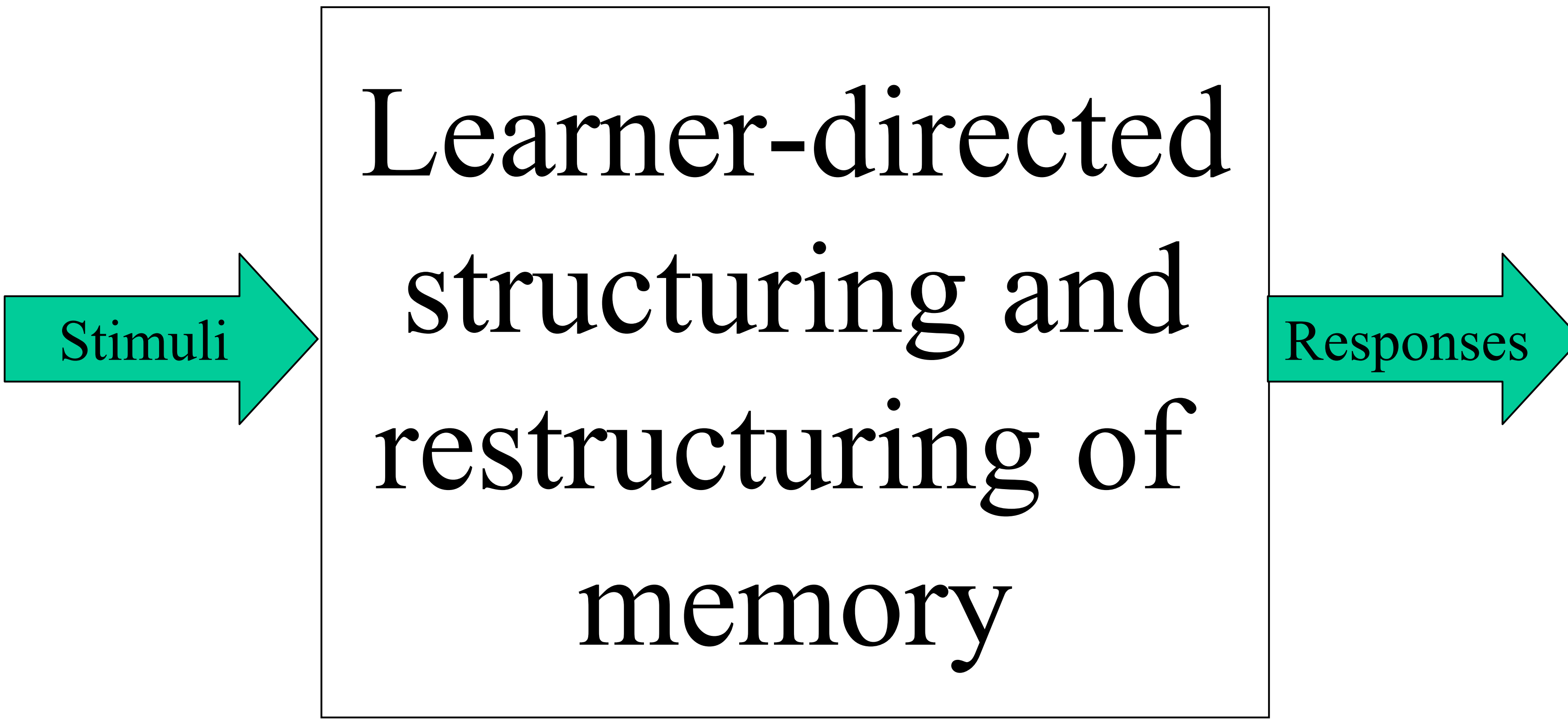
Cognitive, Information Processing

- **Learning as structuring and restructuring memory**
- **Instructional implications**
  - Direct student's attention to key points
  - Emphasize how material is organized
  - Make information more meaningful to learners
  - Encourage active checking of understanding
  - Recognize the limitations of working memory
  - Understand how learners might be representing prior and new information

Why might a cognitive model be inadequate?

- **"Is it going to be on the test?"**
  - Performance focus instead of mastery focus
  - Developing self-regulation of motivation
- **"Can you envision a cognitive learning environment that responds to the four challenges?"**
- **"How will graduates cope with an information rich environment if the four-year curriculum has been designed to facilitate high quality learning of specific engineering topics?"**

Metacognitive



Metacognitive

- **Learning as learner-directed structuring of memory; reflective learner**
- **Elements**
  - Memory: short-term and long-term
  - Processing
  - Executive
  - Metacognitive processor
- **Questions**
  - What learning strategies is the learner currently employing?
  - How well does a learner monitor her/his learning and performance?
  - How well does a learner plan and control her/his learning?

Metacognitive

- **Learner thinks about thinking, meta-cognition.**
- **Instructional implications**
  – Promote reflection, e.g., journals, scripts of problem solving processes (Cowan), cooperative activities, after-action reviews
  – Explicitly teach learning strategies in the context of an engineering course
  – Identify skills required for problem solving, design, lifelong learning and develop modules that will develop these skills

Intelligent Novices

- **Understanding vs. memorizing, appropriate mental strategies**
- **Difficult vs. easy text, appropriate reading strategies**
- **Solve problems and examples from a text in random order**
- **Recognizing poor understanding, and willingness to solicit expert help**
- **Recognizing when expert explanations were making a difference with immediate learning problem**

Brown, A.L., et. al. (1983) "Learning, remembering, and understanding" in P.H. Mussen, ed., *Handbook of Child Psychology*, volume 3: *Cognitive Development*, Wiley

Cowan's Teaching Examples

- **Bridge design**
  - Design and build two different bridges and grade on the lower performance design
- **Problem-solving script**
  - Illustrate script for one type of problem, ask students to develop a script for another type of problem

Cowan, J. (1998) *On Becoming an Innovative University Teacher: Reflection in Action.* Buckingham: SRHE and Open University Press.

Evolution in Cognitive Learning Theory

- **Stage 1: Latin builds mental muscle**
  - Strong methods matter, any subject builds strong methods
- **Stage 2: General problem solving approaches**
  - Strong methods matter, but must present appropriate strong methods
- **Stage 3: Domain-specific instruction**
  - Weak methods matter, concentrate on domain-specific topics
- **Stage 4: Intelligent novices can be fostered**
  - Teaching strong strategies in context

Bruer, J. (1993) *Schools for Thought: A Science of Learning in the Classroom*. MIT Press

Informed Strategy Instruction

- **Include explicit descriptions of the general and/or metacognitive strategies**
- **Include explicit descriptions of when general and/or metacognitive strategies are useful**
- **Include explicit descriptions of why general and/or metacognitive strategies are useful.**

Bruer, J. (1993) *Schools for Thought: A Science of Learning in the Classroom*. MIT Press, p. 75

McMaster Problem Solving Program

Each skill workshop followed a standard pattern:

- Define the skill and clarify its importance
- Put the skill into the context of the other skills being developed.
- Formulate learning objectives and give students a brief pretest.
- Build the skill in a content-independent domain, bridge the skill into a context-dependent domain, and extend the skill
- Allow them to compare their behavior with target behavior
- Help them develop the target behavior through practice and immediate feedback.

McMaster Problem Solving Program

Processing skills are best developed through a three-stage process with reflection.

1. **Build** the skill in a stress-free exercise so that students can focus on the mental processes being used (instead of thinking about both subject-knowledge and the processing skill). In reflection students assessed the degree to which they developed the skill using questionnaires based on learning objectives.

2. **Bridge** those processing skills to apply them in a simplified problem situation in a target subject domain. Reflect on the process used to solve the simplified problem;

3. **Extend** the application of those process skills to any type of problem situation. They reflected on their use of the skill in their subject courses and in their everyday life.

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Expectations

- Course syllabi
- Learning objectives
- Taxonomies of learning
- Competency Matrix
- Rubrics

Question #1: Information Gathering

Individual Exercise

Rate your understanding of each of the preceding concepts about establishing your expectations for students.

0 – No knowledge

1 – Aware of term

2 – Know enough to want to know more

3 – Know enough that topic could be skipped in the workshop

Expectations
Course Syllabus

- **A course syllabus lists the topics that students are expected to learn.**

Expectations

Learning Objectives

- **A learning objective describes expected student behavior under specified conditions.**
  - DO: Focus on expected behavior: solve, apply, etc.
  - DO: Describe conditions under which the expected behavior is to occur.
  - DON'T: Use words such as understand, know, appreciate, value

Expectations

What is Bloom's Taxonomy?

- **Six different levels of learning for any topic**
- **Each level requires mastery of lower levels**

What is Bloom's Taxonomy?

- **Remembering**
- **Understanding**
- **Application**
- **Analysis**
- **Evaluating**
- **Creating**

Expectations

What is Bloom's Taxonomy?

- **Remembering**
  - The ability to learn facts and to remember or recall previously learned materials, ideas or principles.
- **Understanding**
  - The ability to explain ideas or concepts?
- **Application**
  - The ability to use learned material in new and concrete situations.
- **Analysis**
  - The ability to break down material into parts and see relationships. This includes classifying, analyzing and distinguishing the parts.
- **Evaluating**
  - The ability to justify a decision or course of action?
- **Creating**
  - The ability to generate new products, ideas or ways of viewing things ?

Expectations
What is a competency matrix?

	Remember	Understand	Apply	Analyze	Evaluate	Create
Topic 1						
Topic 2						
Topic 3						
Topic 4						

Expectations: What are rubrics?

- For a learning objective, the answer to the question of whether a student has mastered the material is either YES or NO.
- A rubric creates different levels of mastery and provides a description or criteria of satisfaction for each level.

Expectations: What are rubrics?

Table 1

Rubric for Evaluating Composition of Instructional Objectives (IO)

	Unacceptable Performance	Minimally Acceptable Performance	Acceptable Performance	Good Performance	Superior Performance
When given a topic, the learner is able to compose an IO.	Composes an IO that fails to specify all the elements of the definition.	Composes an IO with all the required elements	Composes IOs at the lowest levels of Bloom's taxonomy	Composes IOs at several different levels of Bloom's taxonomy including higher levels	Composes IOs at all six levels of Bloom's taxonomy

Expectations: What are rubrics?

Team Exercise

Pick a task related to teaching and build a rubric for it.

Group Exercise

Course syllabi / Learning objectives

Taxonomies of learning / Competency Matrices / Rubrics

For each of your classes, which of the above methods might you use when describing "What do I want people to learn?"

Group Discussion to generate answer

How do people learn?
What are learning strategies?

- **Rehearsal**
  - Active repetition
  - Example: repeating vocabulary words
  - Example: identifying key ideas
- **Elaboration**
  - Building bridges between new material and existing material
  - Example: fMRI scan on remembering words
- **Organization**
  - Special case of elaboration strategies
  - Imposing an organizational framework on material under study
  - Example: concept map

What is a strategy-level matrix?

	Remember	Understand	Apply	Analyze	Evaluate	Create
Rehearsal						
Elaboration						
Organization						

Expectations and Learning

What is a strategy-level matrix?

	Remember	Understand	Apply	Analyze	Evaluate	Create
Rehearsal						
Elaboration						
Organization						

Team Exercise

Fill in portions of the matrix showing examples of strategies that students might adopt that are appropriate for a given level of learning.

Foundation Coalition Examples

Part II

FC Partner Institutions

- **Arizona State University (ASU)**
- **Rose-Hulman Institute of Technology (RHIT)**
- **Texas A&M University (TAMU)**
- **University of Alabama (UA)**
- **University of Massachusetts-Dartmouth (UMD)**
- **University of Wisconsin-Madison (UW)**

FC Core Competencies

- Active/Cooperative Learning
- Students Teams in Engineering
- Increasing Participation of Women and Underrepresented Minorities in Engineering
- Technology-Enabled Learning
- Curricular Integration
- Continuous Improvement through Assessment and Evaluation
- Managing Curricular Change

FC First-Year Curricula

- **UMD First-Year: IMPULSE**
  - Integrated Mathematics, Physics, Undergraduate Laboratory Science, Engineering
- **ASU First-Year: EnGAGE**
- **RHIT First-Year: IFYCSEM**
  - Integrated, First-year Curriculum in Science, Engineering and Mathematics
- **TAMU First-Year: No name**
- **UA First-Year: TIDE**
  - Teaming, Integration, Design, Engineering
- **UW First-Year: LINKS**

IMPULSE
UMD First-Year Cohorts

250 Entering Students	Calculus II+	Integrated	5%
		Independent	5%
	Calculus I	Integrated	40%
		Independent	15%
	Pre-calc, trig, alg	Linked	25%
		Independent	10%

Integrated – tightly interconnected section of Engineering, Calculus, Physics and English

Linked – students enroll in common sections of two or more of the following: Engineering, Calculus, Physics, English

Independent – independent sections of first-year courses

IMPULSE First-Year Curriculum

Courses	Fall	Spring
• Physics for Sci. & Engr. I, II	4	4
• Principles of Modern Chem. I, II	3	3
• Intro. to Applied Chem. II	0	1
• Critical Writing and Reading I	3	0
• Intro. to Applied Sci. & Engr. I, II	3	2
• Calc. for Applied Sci. & Engr. I, II	4	4
• **IMPULSE Total Credits**	**17**	**14**
• **Program Specific (not IMPULSE)**	**0**	**3**
• **Total Credits**	**17**	**17**

University of Massachusetts-Dartmouth

- **Classroom layout & equipment**
  - Remodeled three classrooms with tables that seat four students and have two computers (48 seats)
- **Software & Applications**
  - Maple and Excel
  - Based on Studio Physics model (RPI), students perform physics and chemistry experiments in the classroom, acquire, display and analyze data
- **Audience**
  - Freshman & sophomore engineering majors

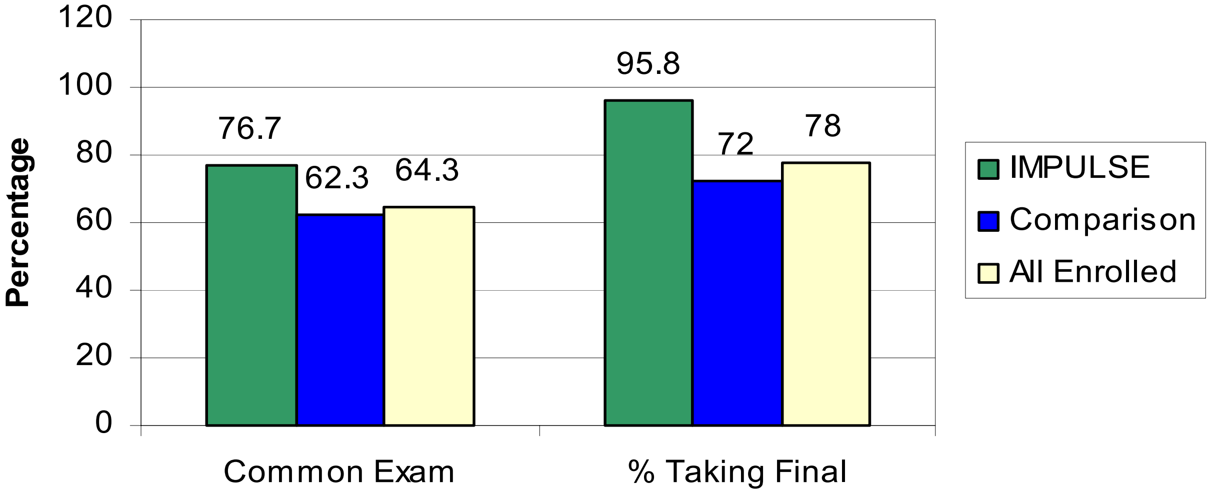
University of Massachusetts-Dartmouth

IMPULSE

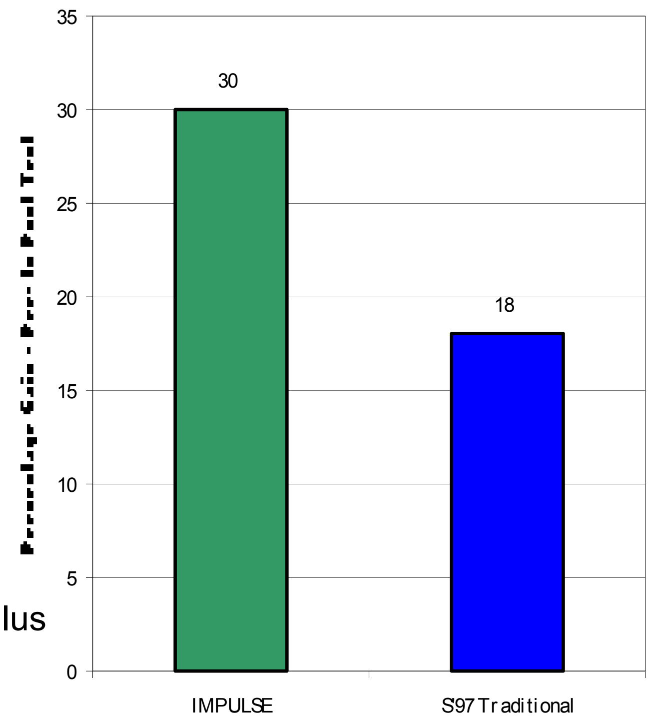
Classroom

Freshman Performance at UMass-Dartmouth Calculus and Physics

Performance in Calculus (Fall Quarter 1998)



Performance on the Force Concept Inventory



IMPULSE - Integration of Math, Physics, Undergraduate Laboratory Science, English, and Engineering - Curriculum.

- Students in the IMPULSE have a higher average (77) on a common calculus exam than the average (62) students in the 19998 comparison group.
- A higher percentage of students (96%) in the IMPULSE program are still enrolled in calculus at the final exam when compared to the percentage of students (72%) in a comparison group.
- Students in the IMPULSE program demonstrated a larger gain on the Force Concepts Inventory (FCI), a national normed physics tests, than students in the 1997 traditional curriculum.

University of Massachusetts Dartmouth

EnGAGE
ASU First-Year Cohorts

800 Entering Students	Calculus II+	Linked	10%
		Independent	10%
	Calculus I	**Integrated**	**10%**
		Linked	20%
		Independent	20%
	Pre-calc, trig, alg	Linked	20%
		Independent	20%

Integrated – tightly interconnected section of Engineering, Calculus, Physics and English

Linked – students enroll in common sections of two or more of the following: Engineering, Calculus, Physics, English

Independent – independent sections of first-year courses

Freshman Integrated Program in Engineering (FIPE)

F '94 - S '97

- English - 3 hrs F&S
- Physics - 4 hrs F&S
- Calculus - 4 hrs F&S
- ***Engineering - 4 hrs F***
- Chemistry - 4 hrs S

15 hours/semester

F '97 - present

- English - 3 hrs F&S
- Physics - 4 hrs F&S
- Calculus - 4 hrs F&S
- ***Engineering - 2 hrs F&S***

13 hours/semester

Arizona State University

Sample

ASU

Classroom

Foundation Coalition

Projects <---> Integration, Active Learning, Technology

Engineering:
- Design Process
- Design Tools
- Teamwork

English:
- Rhetorical Skills
- Presentation Software
- Peer Review

Projects

Calculus:
- Math Skills
- Computer Algebra

Physics:
- Science Skills
- Data Capture
- Lab Technique

First Semester Projects

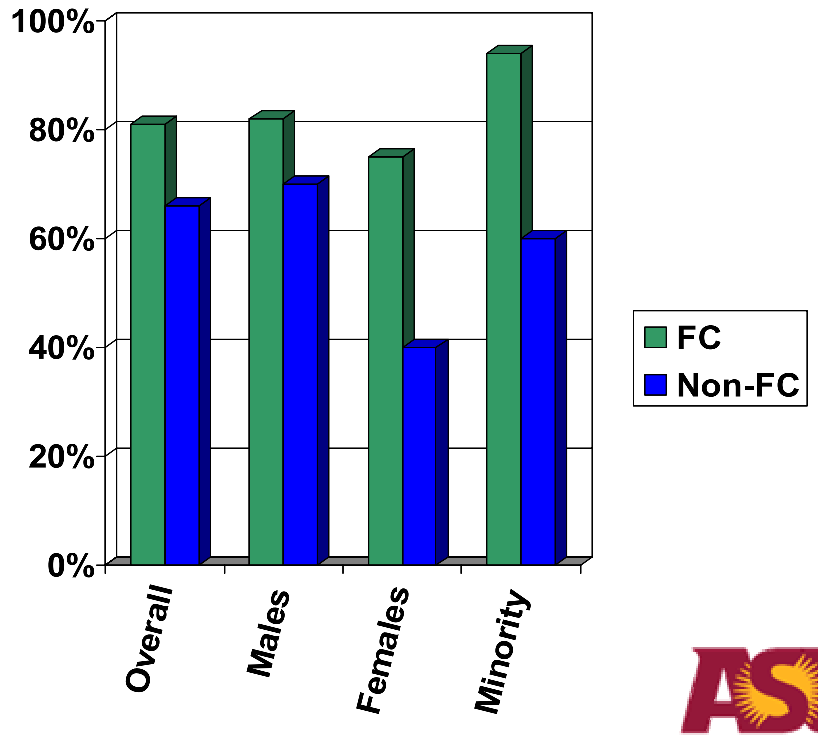
- Kinematics → The Catapult
- Newton's Laws → The Bungee Jump, The Roller Coaster
- Rotational Motion → The Trebuchet, The Roller Coaster

Second Semester Projects

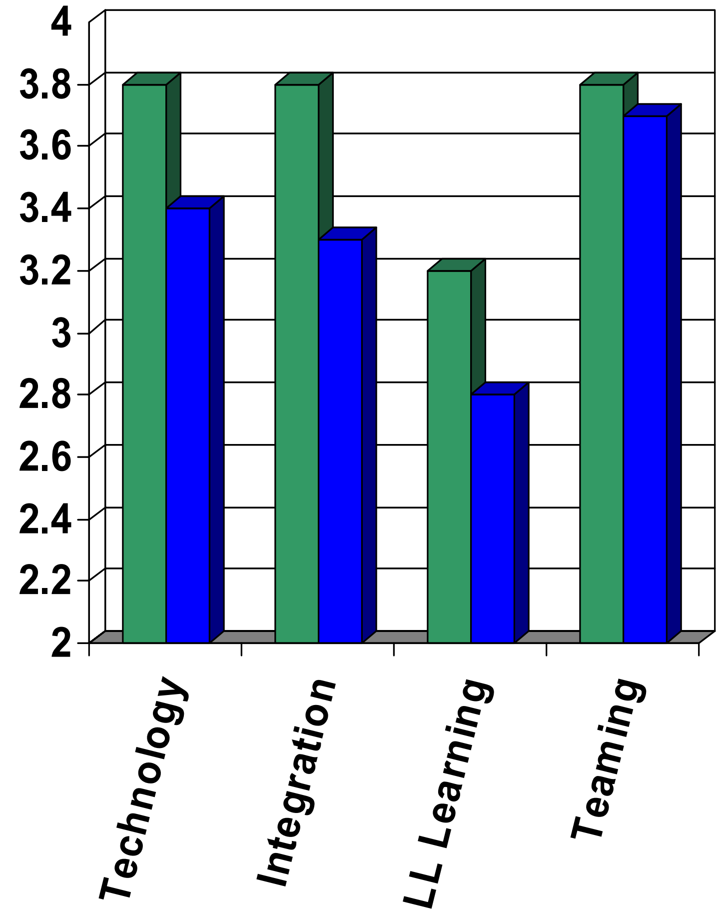
- Physical Signals → Sensors/Detectors
- Physical Signals → Hydroelectricity
- Differential Equations → The Analog Computer
- Differential Equations → Traffic Flow
- Wave Motion → The Seismometer

Impact

Retention



Attitudes toward FC core ideas



Arizona State University

EnGAGE Program - Option 2

- **Three Course Groups - chosen from this list**
  - Engineering Design (4)
  - Chemistry (4)
    - Chemistry for Engineers or General Chemistry
  - English Composition (3)
  - Computer Programming (3)
    - Programming (C++) or Programming (Java) or Principles of Computing
  - University Physics (4)
  - Mathematics (3 or 4)
    - Precalculus or Calculus
  - Digital Design (3)

EnGAGE Program - Option 2

- Fall Semester only
- 12 combinations from list
- Student groups of 20-25
- Students expected to take at least one more course

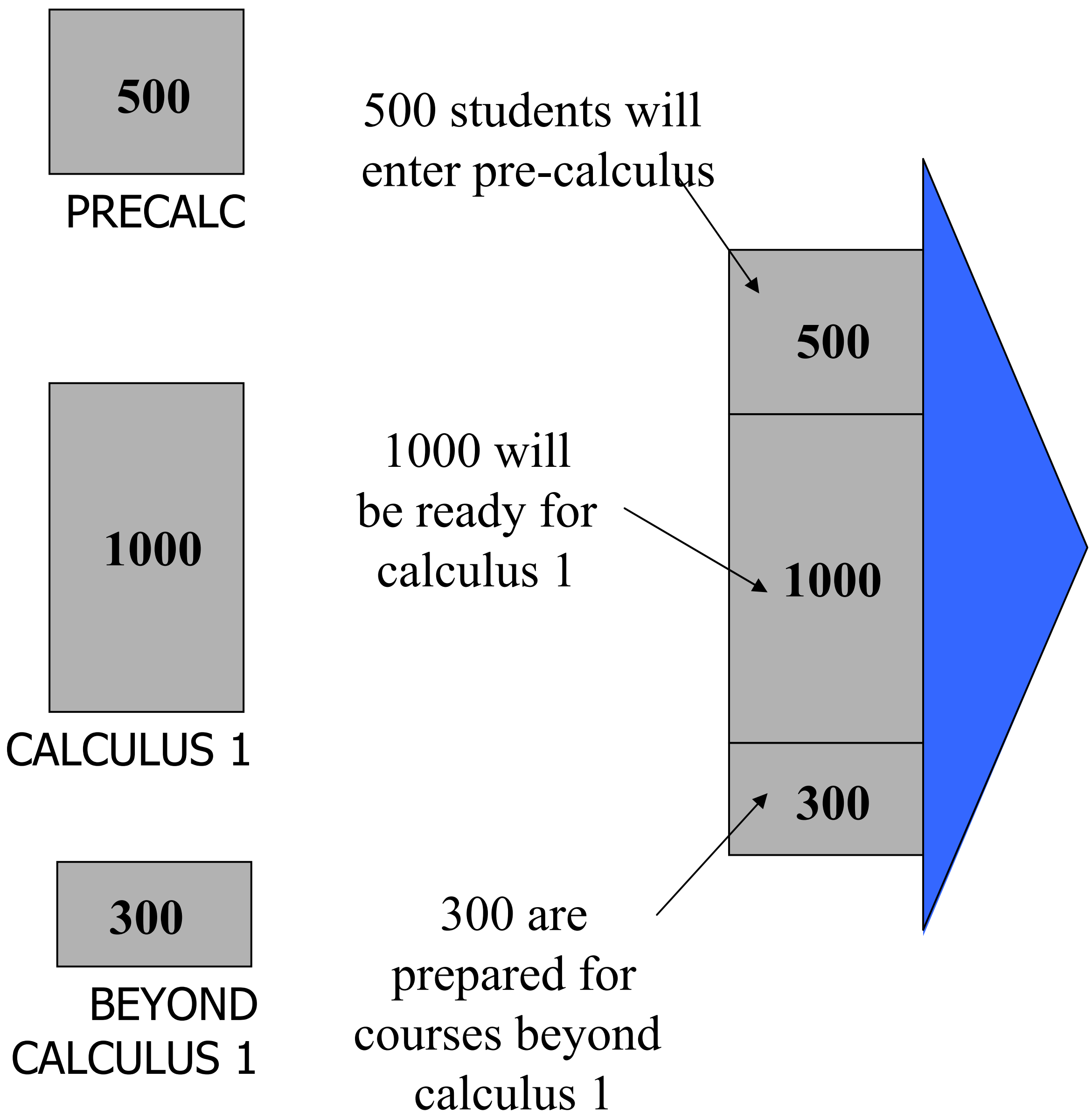
TAMU First-Year Cohorts

1800 Entering Students	Calculus II+	Linked	3%
		Independent	14%
	Calculus I	Linked	47%
		Independent	8%
	Pre-calc, trig, alg	Linked	17%
		Independent	11%

Linked – students enroll in common sections of two or more of the following: Engineering, Calculus, Physics, English

Independent – independent sections of first-year courses

CURRICULUM OPTIONS FOR STUDENTS



First Year

500
PRECALC

Precalc, Chem, Engr 0 (300)
Independent Courses (200)

1000
CALCULUS 1

Calc 1, Phys 1, Engr 1, Engl 1 (100)	Calc 2, Phys 2, Engr 2, Chem (300)
Calc 1, Phys 1, Engr 1 (600)	Calc 2, Phys 2, Engr 2 (200)
Calc 1, Engr 1 (150)	Calc 2, Engr 2, Chem (300)
Independent Courses (150)	Independent Courses (300)

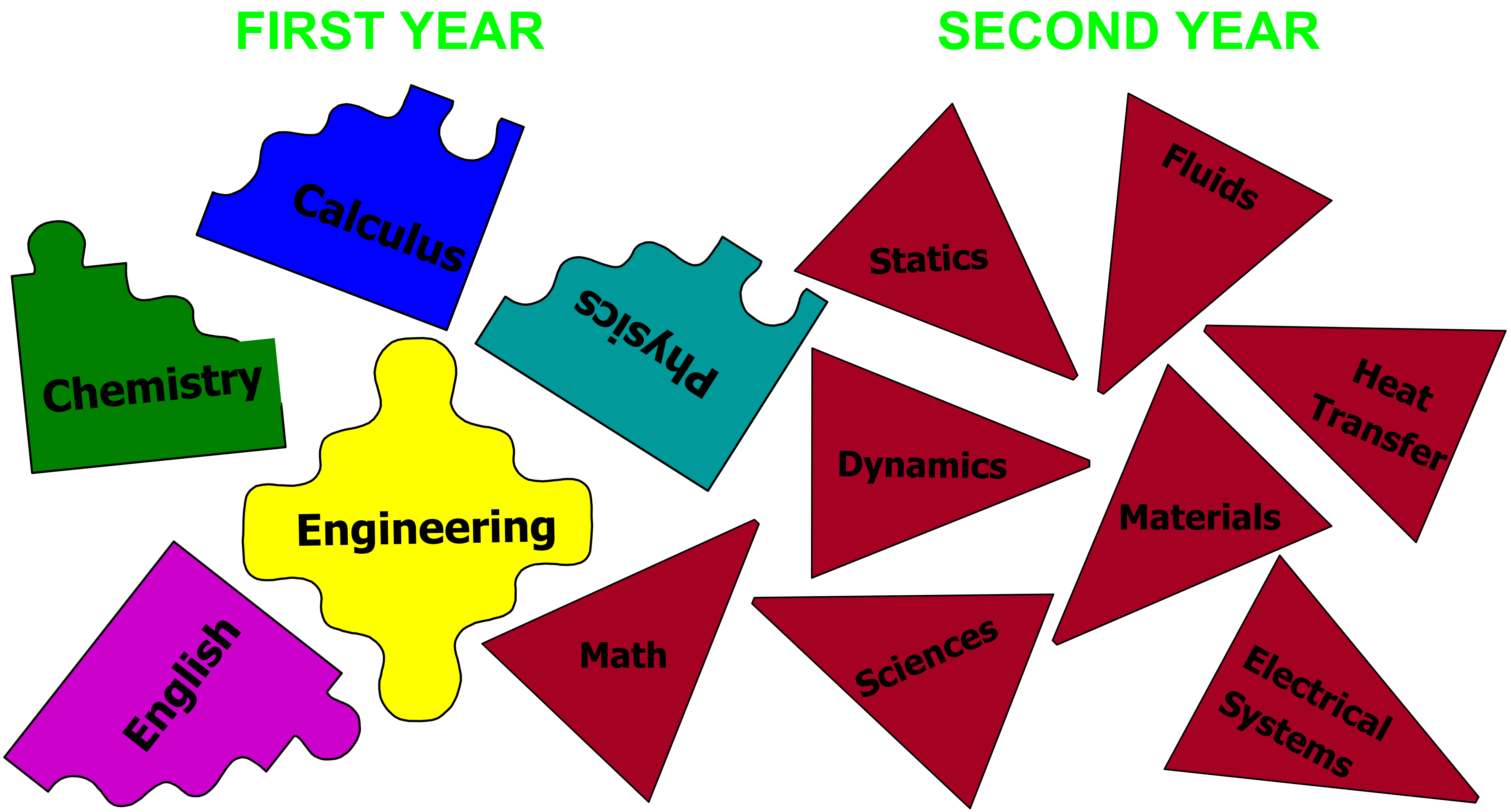
300
BEYOND CALCULUS 1

Calc 2, Engr 1 (50)
Independent Courses (250)

Integration of Courses

- **First Year**
  - –Engineering
  - –Physics
  - –Chemistry
  - –Calculus
- **Second Year**
  - – Engineering Sciences
    - Materials
    - Thermodynamics
    - Statics/Dynamics
    - Mechanics
    - Circuits
  - – Calculus
- **Upper Division**

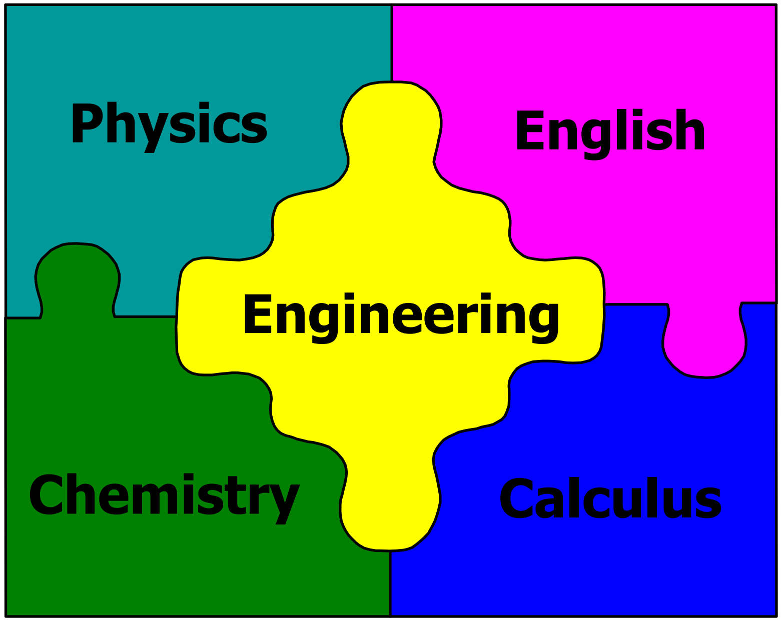
In the old curriculum, students viewed the foundation courses as disjointed and unrelated.



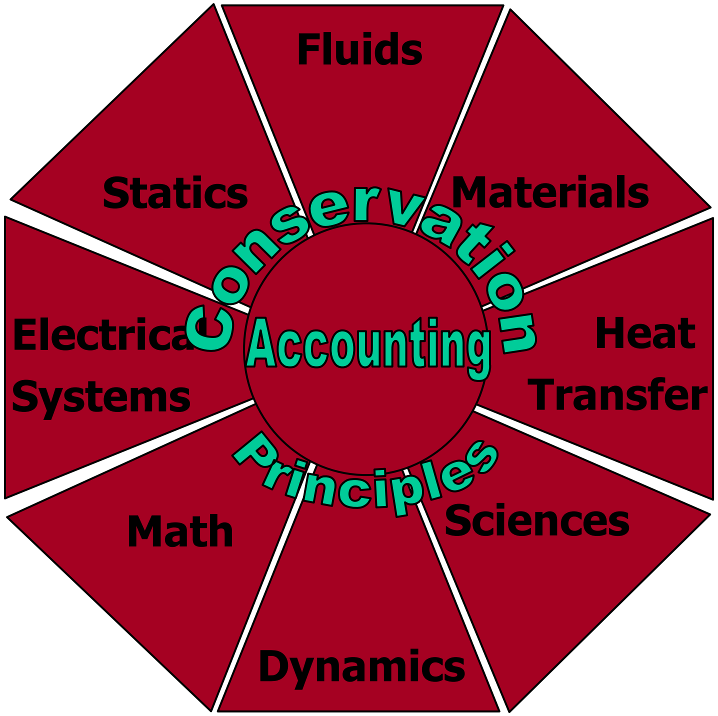
University Core Curriculum Requirements

In the integrated curriculum, course material clearly illustrates how these courses relate to the engineering field.

FIRST YEAR



SECOND YEAR



University Core Curriculum Requirements

CASE STUDY TOPICS

APPLIED MATERIALS - *Semiconductor Process Equipment-Cathode Base Field Failures*

COMPAQ - *Weighing Need to Differentiate VS. Benefits of Standardization*

DYNACON - *Launching Structures in the Offshore Marine Industry*

EXXON CHEMICAL - *Critical Care-A Case Study in Problem Solving and Team Work*

MOTOROLA - *Bringing Up a New FAB Plant*

TEXACO - #1*Getting Natural Gas to Market* #2 *Storage Tank Fire Investigation*

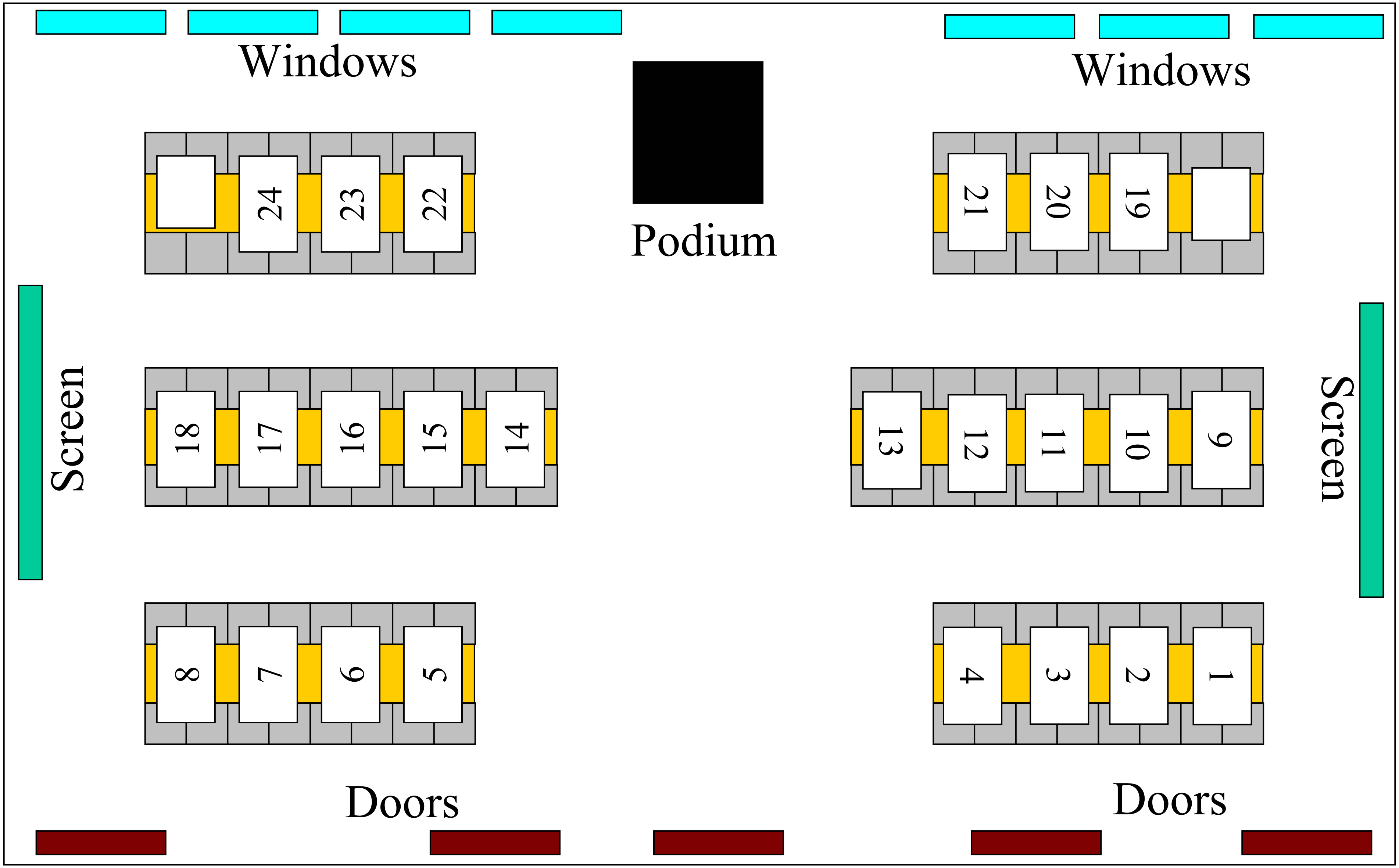
TU ELECTRIC - #1 *Over-speed of Auxiliary Turbines* #2 *Install COHPAC (Compact Hybrid Particulate Collector) at Big Brown Steam Electric Station*

LOCKHEED MARTIN - *Common Missile Warning System – Optical Sensor Placement*

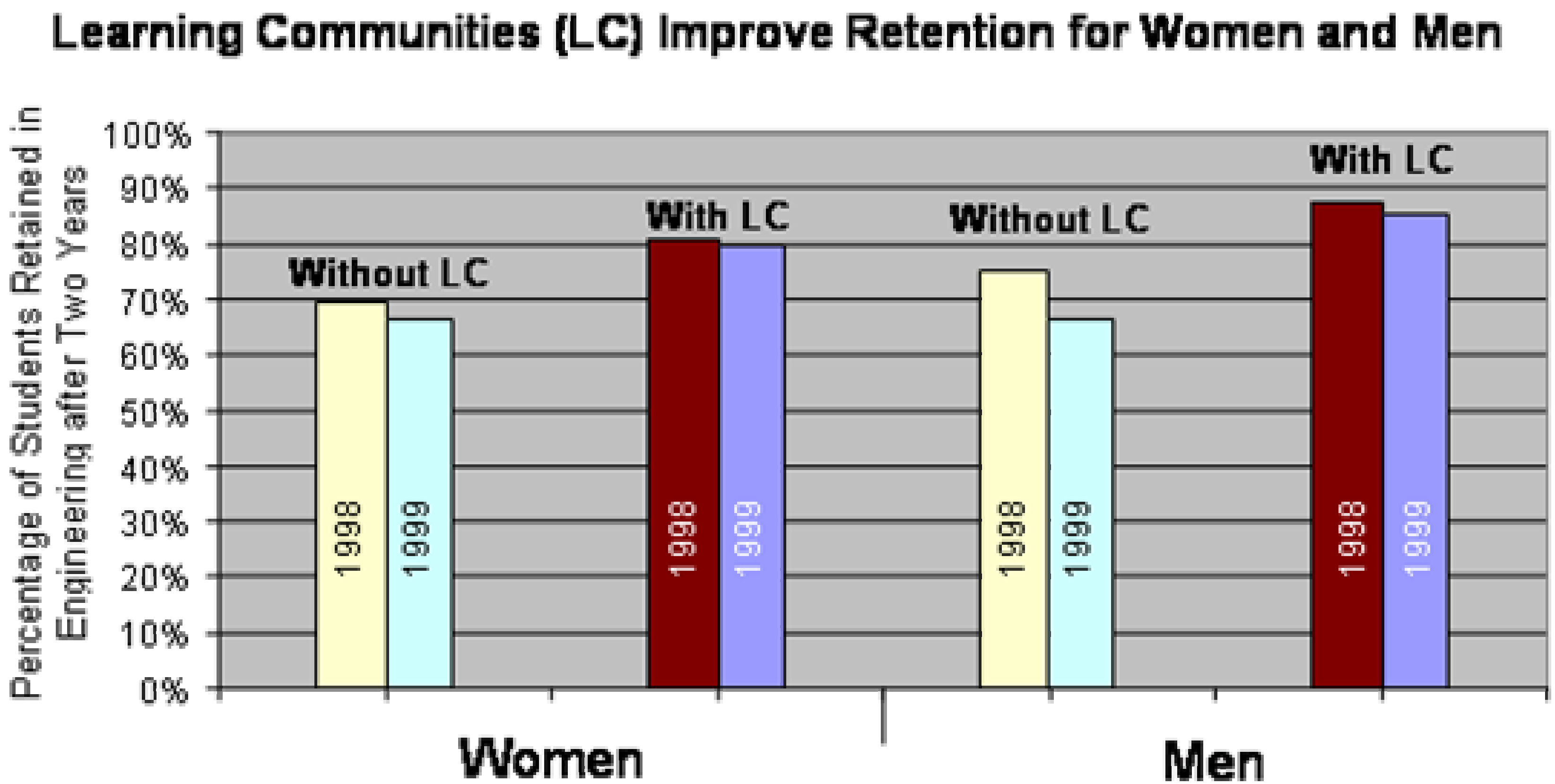
Texas A&M University

- **Philosophy**
  - Classroom technology must be scalable for large classes (~100)
- **Classroom layout & equipment**
  - Remodeled about 10 classrooms for first-year and sophomore courses
  - One computer per two students
  - Departments have constructed their own classrooms, more are planned
- **Software & Applications**
  - Microsoft Office, Maple, AutoCAD, Eng. Equation Solver (EES), Internet
  - EE has students design, simulate, construct, measure and compare behavior of circuits. Class uses NI hardware and software.
- **Audience**
  - Freshman and sophomore engineering students
  - Specialized classes in specific disciplines

CVLB 319: ENGR 112 Team Layout
Sections 501 - 503

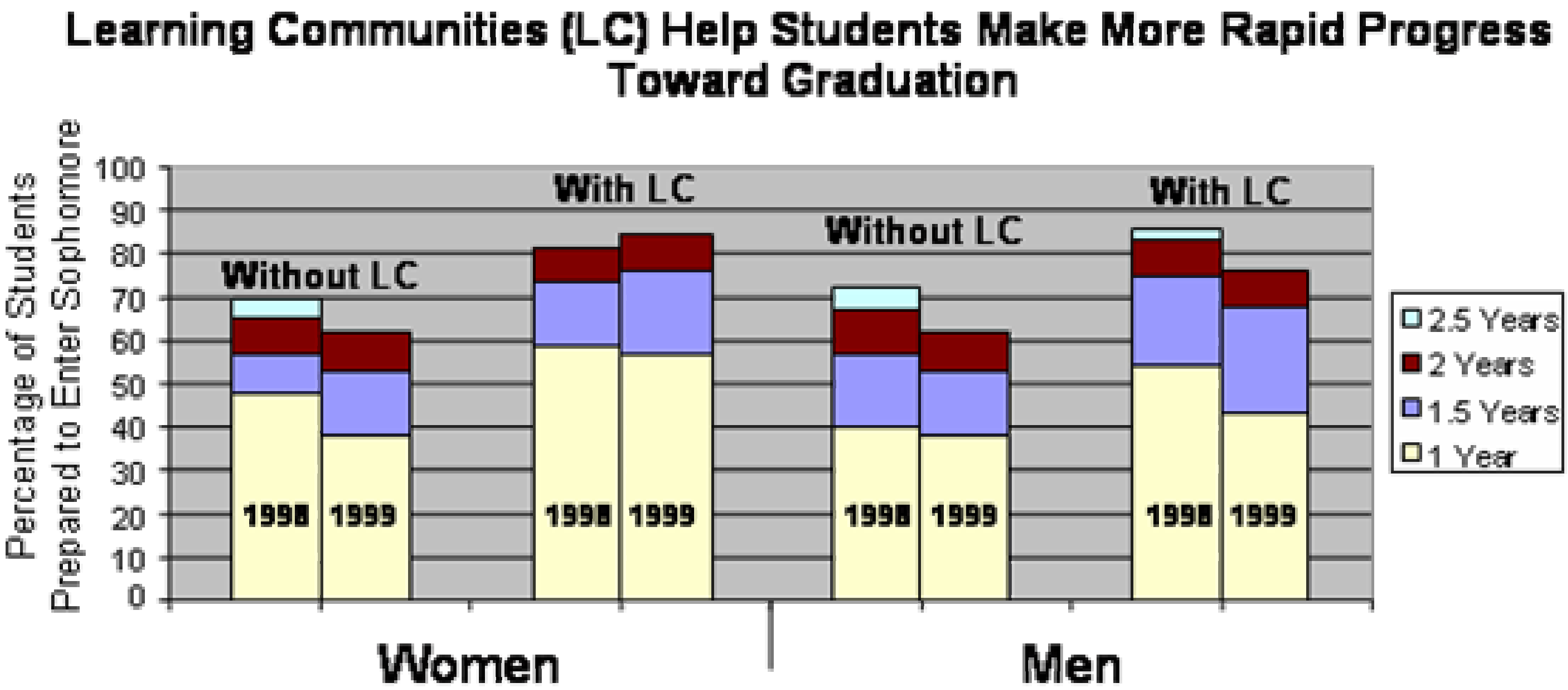


TAMU Learning Communities



Students who participate in learning communities (With LC) are retained in engineering at a much higher rate than similar students who do not participate in learning communities (Without LC) during their first year at A&M.

TAMU Learning Communities

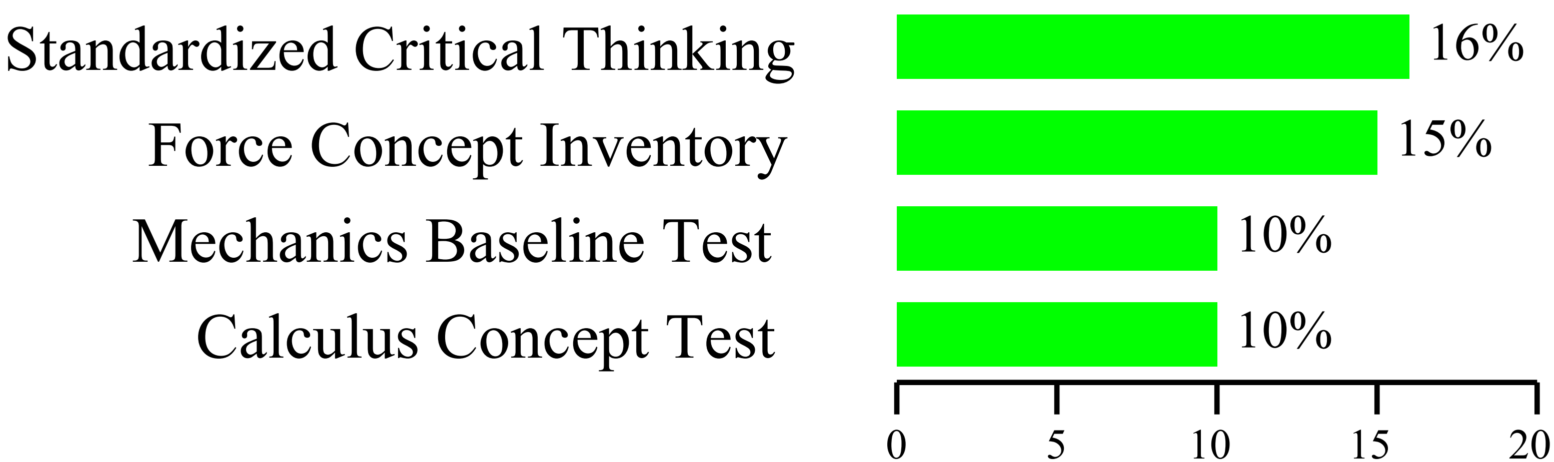


The graph shows the percentage of the students prepared to enter sophomore engineering courses after completing a set of require courses called the Common Body of Knowledge courses. At every point in time after the students entered Texas A&M University, the percentage of students who participated in learning communities (With LC) is greater than the percentage of students who did not participate in learning communities (Without LC).

STUDENT PERFORMANCE ON STANDARDIZED TESTS

When compared to equivalent students in traditional engineering programs, after one year, students in the new curriculum perform better on standardized tests.

Test | **% Gain Greater than Traditional**



REDUCED AVERAGE TIME TO GRADUATION

- Students in the new curriculum show a significant reduction in class repetition (fewer Ds, Fs, & Qs)
- These students complete foundation course work and graduate a semester sooner (on average) than students who are not involved in the new curriculum

TIDE
UA First-Year Cohorts

400 Entering Students	Calculus II+	Linked	5%
		Independent	1%
	Calculus I	Integrated	40%
		Linked	2%
		Independent	1%
	Pre-calc algebra & trig.	Linked	20%
		Independent	1%
	Pre-calc algebra	Linked	25%
		Independent	1%

Integrated – tightly interconnected sections of Engineering, Calculus, Physics and English

Linked – students enroll in common sections of two or more of the following: Engineering, Calculus, Physics, English

Independent – independent sections of first-year courses

TIDE – How are math and physics different?

Traditional Math	TIDE Math
• 4 lectures/week, no recitation • No graded homework • Computers not used	• **3 lectures/week, one 2-hr weekly recitation** • **Homework is graded** • **Computer software used in class and recitation** –Maple, Matlab
Traditional Physics	**TIDE Physics**
• Computers not used • Topics not linked to other classes	• **Computer software used in lecture and lab** –Excel, Maple, Interactive Physics • **Some integration with Math & Engineering** • **Studio Physics - Spring 2002**

TIDE – How is engineering different?

Traditional Engineering (Fall)	TIDE Engineering (Fall)
• Traditional board drafting (~1.5 hr) • AutoCAD (~1.5 hr)	• Sketching (~0.5 hr) • Intro to engineering and disciplines, problem solving and computer "tools" (~1 hr) • Design projects (~1½ hr) – Reports, presentations – Teaming skills
Trad. Engineering (Spring)	**TIDE Engineering (Spring)**
• Fortran programming (~3 hr)	• MATLAB programming (~1½ hr) • Design projects (~1½ hr) –Reports, presentations –Teaming skills

University of Alabama

- **Philosophy**
  - Technology in classrooms, classrooms convenient to students (one new classroom in “engineering dorm”)
- **Classroom layout & equipment**
  - Remodeled six different classrooms
  - Tables for four, one computer per two students
  - Departments constructing their own classrooms
- **Software & Applications**
  - Microsoft Office, compilers, MATLAB, Maple
- **Audience**
  - Freshman engineering students
  - All students in introductory computing sequence

Alabama Classroom Layout

- **Several classroom formats exist**
  - All have computers at student desks, instructor console, projection system
  - Primarily used for lower-division classes

LINKS
UW First-Year Cohorts

700 Entering Students	Calculus II+	Linked	3%
		Independent	30%
	Calculus I	Linked	6%
		Independent	44%
	Pre-calc, trig, alg	Linked	5%
		Independent	12%

Linked – students enrolled in LINKS, common sections of pairs of the following courses: Engineering and Technical Communication, Calculus and Chemistry. UW students have many other opportunities to participate in learning communities

Independent – independent sections of first-year courses

Roles of Student Teams

- Students work to improve their team skills
- Students work on team assignments, including one or more projects
- Student teams provide interpersonal support for students when they are struggling
- Student teams provide nuclei for larger communities across cluster

Industry Participation - Ideas

- Adoption of a team (of 4 students) or an entire cluster (of 96 students)
- Industry teams would visit their team/cluster 3-6 times a semester
- Industry would develop team projects for a 3-4 week duration based on "real world" problems and the student's skill level
- Industry would help in the introduction and evaluation of projects
- Industry would serve as e-mail consultants to team/clusters
- Deliver course lectures on subjects such as ethics, design process, documentation, teaming, and/or communications
- Host cluster for a field trip to industry
- Develop a case study to be presented by engineers in the classroom
- Send new hires back to the classroom to discuss perceptions and realizations of the workplace
- Send an experienced engineering to talk to the class about their projects
- Conduct industry training like teaming, conflict management, communications, etc.
- Industry do mock interviews, resume writing, dinner with discussion

Industry Participation - FC

- **Host cluster for a field trip to industry**
  - UA Pilot Program
- **Develop a case study to be presented by engineers in the classroom**
  - TAMU First-Year Program
- **Conduct industry training like diversity, conflict management, communications**
  - TAMU First-Year: Industry-conducted workshops on diversity, conflict management

Role of First-Year Projects

- Provide students opportunities to apply an engineering design process
- Provide students opportunities to apply their teams skills to an extended project
- Provide students opportunities to connect their mathematics and science concepts to practice of engineering

FC Publications on Learning Communities

1. Morgan, J., J. Rinehart and J. Froyd, "Industry Case Studies at Texas A&M University", *Proceedings, 2001 ASEE Annual Conference*, ASEE, Albuquerque, NM, 24-28 June 2001
2. Malavé, C., et al., “Inclusive Learning Communities at Texas A&M University—A Unique Model for Engineering,” Proceedings of the First Conference on Creating and Sustaining Learning Communities: Connections, Collaboration, and Crossing Borders, Tampa, FL, March 10–13, 1999, Web Publication: http://www.usf.edu/~lc/conf
3. Richardson, Jim, Carlos Corleto, Jeff Froyd, P. K. Imbrie, Joey Parker and Ron Roedel, “Freshman Design Projects in the Foundation Coalition,” *Proceedings, 1998 Frontiers in Education Conference*, Tempe, AZ, November 1998, Web Publication: http://foundation.ua.edu/publications/fie98/1388.pdf
4. Learning Communities Annotated Bibliography, Web Publication: http://www.engr.wisc.edu/services/weel/coalition/bibliography.html

FC Sophomore Curricula

- **Conservation and accounting framework** for engineering science provides the foundation for FC sophomore curricula.

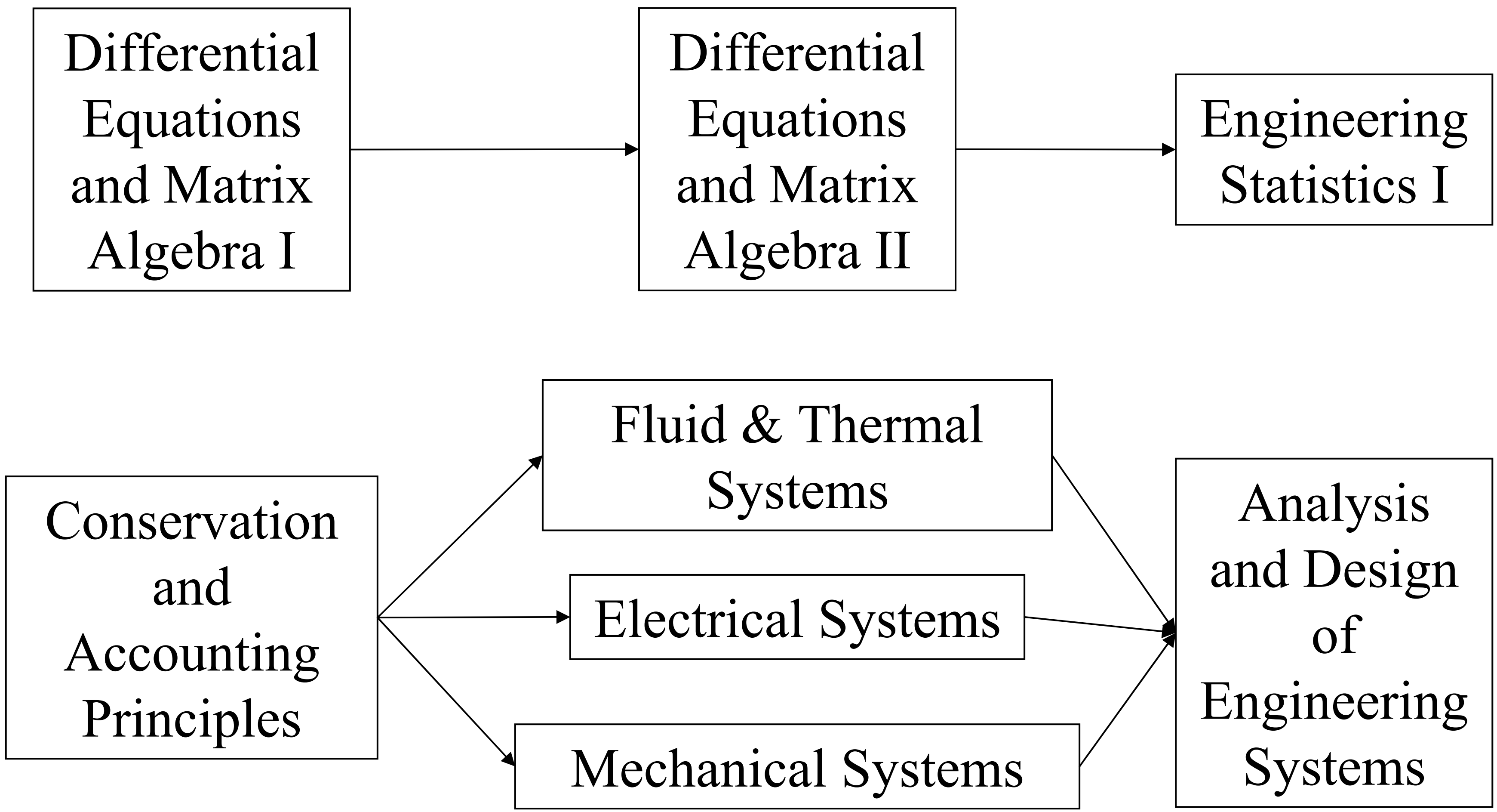
- RHIT: **SEC**
  – Sophomore Engineering Curriculum

- TAMU: **Engineering Science Curriculum**

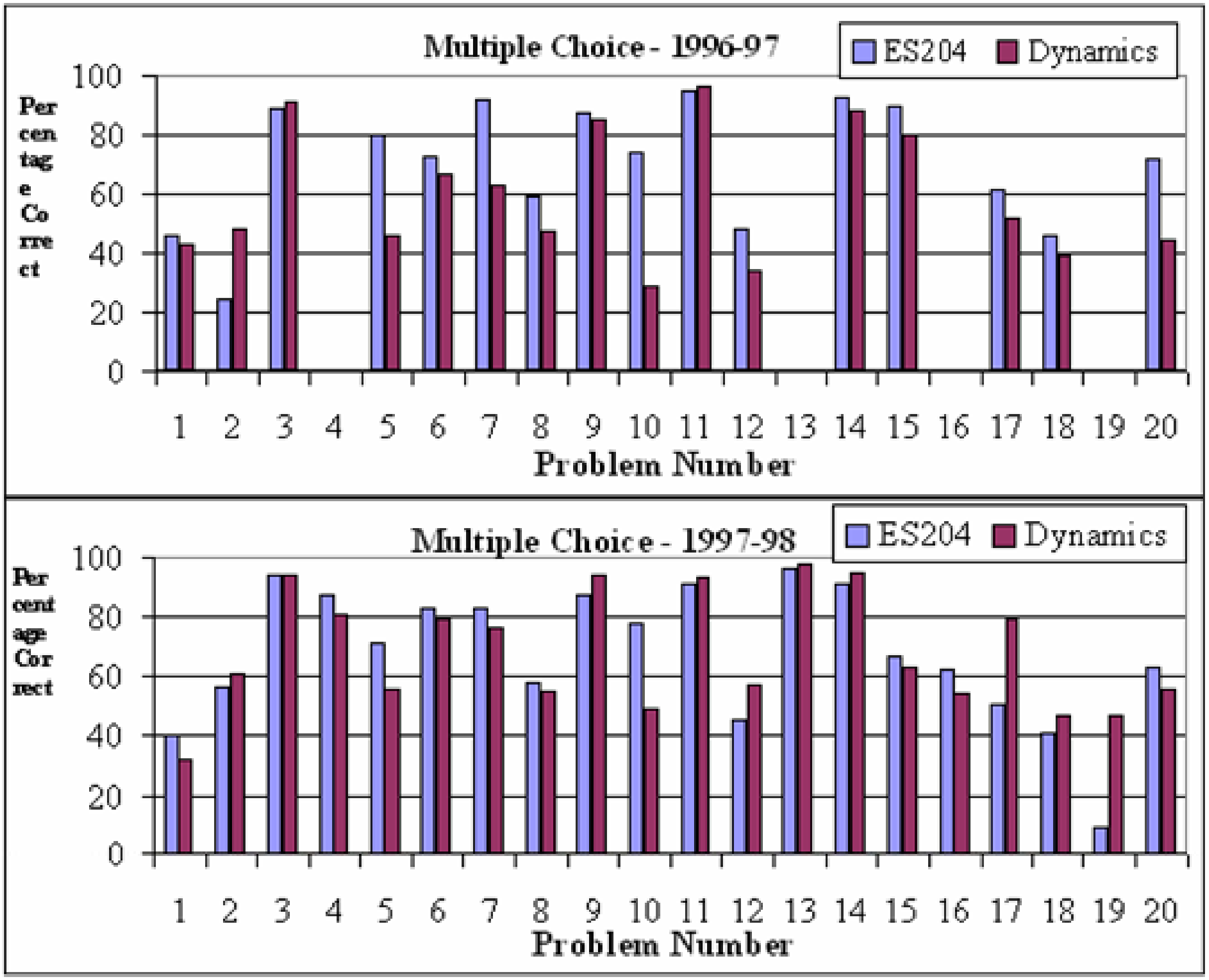
Conservation and Accounting Framework

- **System concept**
  - Identify a system, boundary, and surroundings
- **Extrinsic properties**
  - Identify the extrinsic property(ies) to be tracked
- **Construct a balance equation(s)**
  - Include amount of property entering/leaving the system, amount generated/consumed within system, and amount accumulated within system
- **Conserved properties**
  - Neither generated nor consumed within any system, e.g., mass/energy, charge, linear momentum

RHIT Sophomore Engineering Curriculum



RHIT SEC Student Performance



The graphs on the left compare the performance of students in the sophomore engineering curriculum (ES204) with the performance of students in dynamics. The comparison is based on the multiple choice questions used on the common dynamics final exam. On most questions the ES204 students scored as well or better than students in dynamics.

RHIT SEC Student Performance

Prob. #	1996-97			1997-98		
	SEC ES204	Dynamics	Difference	SEC ES204	Dynamics	Difference
21	33.3	23.3	10	36.8	17.0	19.8
22				70.1	22.0	48.1
23				46.0	6.0	40.0

The above table compares the percentage of students with correct answers for the workout (longer, more complex) problems. To reduce the influence of a particular professor the numbers were obtained by averaging the results from five dynamics sections (three professors) and from four ES204 sections (three professors). Workout problems were designed to be longer, more difficult and required multiple steps and concepts. The students in the SEC curriculum did significantly better than those taking the traditional dynamics course.

Course Components

Each engineering major chooses sophomore level courses from the following five courses based on the conservation and accounting framework (CAF).

- Engineering Mechanics (using CAF)
- Engineering Thermodynamics (using CAF)
- Introduction to Materials (using CAF)
- Continuum Mechanics (using CAF)
- Electrical Systems (using CAF)

TAMU Engineering Science Curriculum
Student Performance

Engineering Science Achievement Examinations

	Core Group		Comparison Group	
	Aver.	Std. Dev.	Aver.	Std. Dev.
Statics	0.65	0.06	0.78	0.06
Dynamics	0.51	0.08	0.35	0.08
Thermodynamics	0.66	0.07	0.57	0.07

Active/Cooperative Learning

Overview

- **What is ACL?**
- **Why ACL?**
- **What does ACL involve?**
  - Components of ACL
- **ACL Strategies**
- **Constructing ACL class exercises**

What is ACL?

- **Active Learning**
  - *When using active learning students are engaged in more activities than just listening. They are involved in dialog, debate, writing, and problem solving, as well as higher-order thinking, e.g., analysis, synthesis, evaluation.*

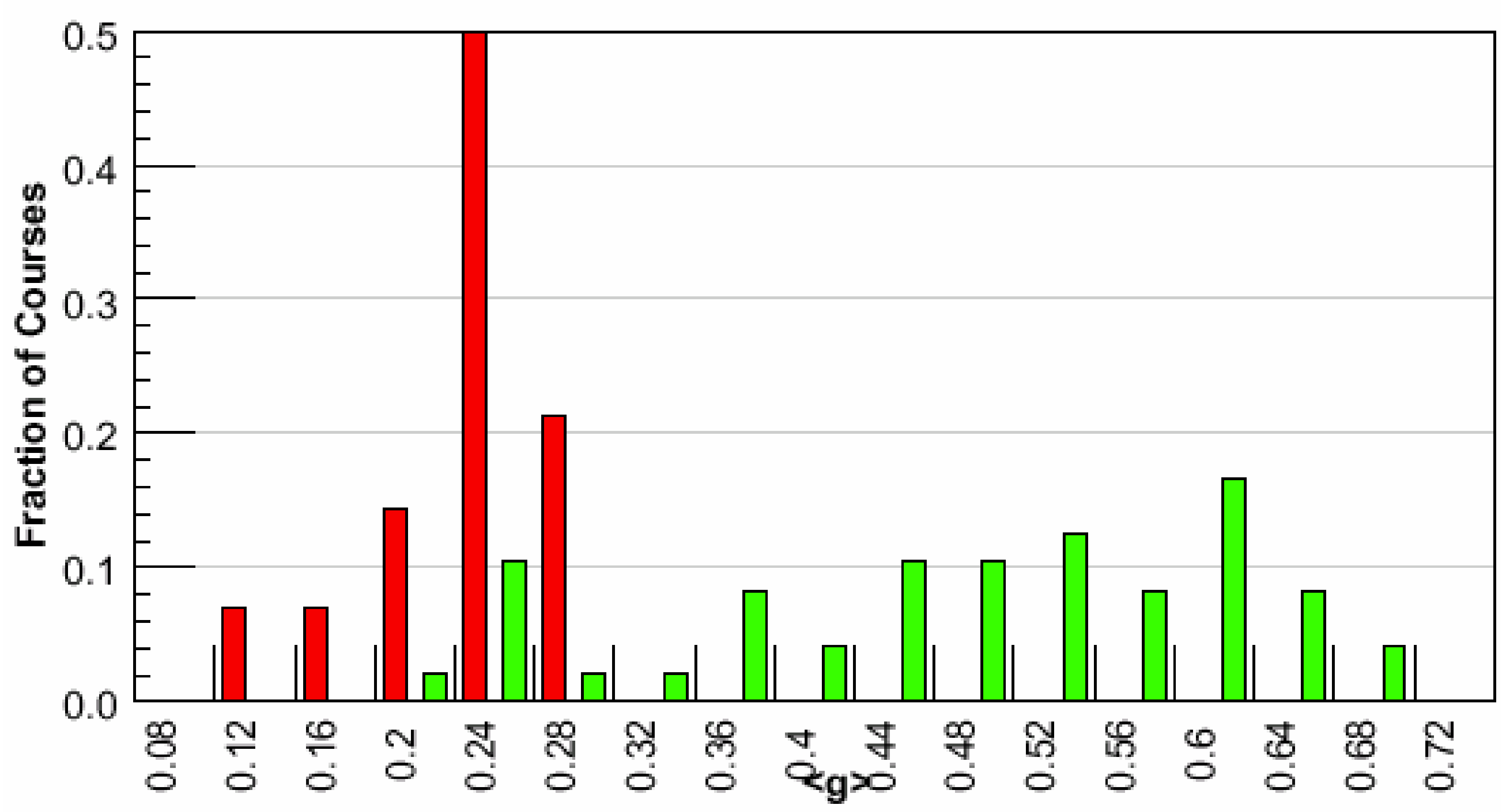
What is ACL?

- **Cooperative Learning**
  - *Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning. Five essential components:*
    1. *Clear, positive interdependence between students*
    2. *Face-to-face interaction*
    3. *Individual accountability*
    4. *Emphasize interpersonal and small-group skills*
    5. *Processes must be in place for group to review and improve effectiveness*

Team Exercise

- (5 minutes) Scan through the handout on the introduction to ACL
- (5 minutes) Share questions and insights within the team
- (x minutes) Questions and Answers

Why Active/Collaborative?



Why Active/Collaborative?

- First, Springer, Stanne, and Donovan published a meta-analysis [1] of thirty-nine research studies conducted since 1980 on effectiveness of small group learning in science, mathematics, engineering and technology [??, could point to PowerPoint presentation]. They summarized their results.
- The meta-analysis demonstrates that various forms of small-group learning are effective in promoting greater academic achievement, more favorable attitudes toward learning, and increased persistence through SMET courses and programs. The magnitude of the effects reported in this study exceeds most findings in comparable reviews of research on educational innovations and supports more widespread implementation of small-group learning in undergraduate SMET.
- Quantitatively, the results for increased performance and retention were stated in the following manner.
- The reported effects are relatively large in research on educational innovation and have a great deal of practical significance. The 0.51 effect of small-group learning on achievement reported in this study would move a student from the 50th percentile to the 70th on a standardized test. Similarly, a 0.46 effect on students' persistence is enough to reduce attrition from SMET courses and programs by 22%. The 0.55 effect on students' attitudes far exceeds the average effect of 0.28 (9) for classroom based educational interventions on affective outcome measures.

ACL Elements (5 total elements)

- **Positive Interdependence** - Team members must rely on each other to accomplish goals.

- **Individual Accountability** - Members are held accountable for doing their share of the work, as well as mastering all material.

ACL Elements (continued)

- **Group Processing** - Teams periodically reflect on what they do well as a team, what they could improve, and what they might need to do differently.
- **Face-to-Face Interaction** - Some or all work should be done by members working together.

ACL Elements (continued)

- **Social Skills** - Team members practice and receive instruction in leadership, decision-making, communication, and conflict management.

Cooperative Learning Strategies

- *Think Pair Share*
- *Think Aloud Paired Problem Solving*
- *JigSaw*
- *Enhanced Lecture*

- *Many more techniques exist*

Cooperative Learning Strategies

Think – Pair - Share

- Applied earlier

Think Aloud

Paired Problem Solving

- Describe briefly

Cooperative Learning Strategies

JigSaw

- Use with material that can be broken into xx independent parts.
- For each part select a member from each team to be the team expert
- Expert groups meet and develop lesson on part.
- Experts present the lesson to the rest of the team.

Enhanced Lecture

- Introductory activity
- Lecturette (10-15 minutes)
- Activity (2 minutes)
- Lecturette (10-15 minutes)
- Activity (2 minutes)
- Lecturette (10-15 minutes)
- Closing activity

Cooperative Learning / Distance Learning

- ***Felder, R.M. and Brent, R. (2001) FAQs. III. Groupwork in Distance Learning," Chem. Engr. Education, 35(2), 102-103, http://www.ncsu.edu/felder-public/Columns/FAQs-3.html***
- ***Make it clear to the students why groupwork is being required.***
  - *Particularly important for students in distance courses, whose learning preferences tend to favor working independently.*
- ***Form small teams that are balanced in knowledge and skills.***
  - *Teams of three or four are large enough to provide adequate diversity of opinions, experiences, and learning styles, but not so large that individual members can successfully hide.*
  - *Groups of all strong students or all weak students should be avoided. If possible, at least one member of each team should have experience with the computer tools to be used to complete the assignments.*
- ***Give clear directions regarding both the assignments and the communication tools.***
  - *Virtual groups may find it particularly frustrating to have to decipher muddy directions about what to do and how to do it, and their frustration could hurt both their motivation and their performance. Give short preliminary assignments that require the team members to demonstrate their mastery of the communication software.*

Cooperative Learning / Distance Learning

- ***Monitor team progress and be available to consult when teams are having problems.***
  - *Be proactive against procrastination, which could be worse when teams are separated.*
  - *Appoint team coordinators whose responsibilities are to keep their teams on task and to report on progress and problems at regular intervals. Periodically rotate this role among team members.*
  - *Prompt groups that are not meeting frequently enough and offer guidance if they appear to be stuck.*
- ***Intervene when necessary to help teams overcome interpersonal problems.***
  - *Suggest strategies like active listening to resolve conflicts. (Each side makes its case, and the other side has to repeat that case to the first side's satisfaction without attempting to counter it. When both sides have had their say, a resolution is sought.)*
  - *Consider conducting such sessions by videoconference or telephone rather than asynchronously.*
- ***Collect peer ratings of individual citizenship and use the ratings to adjust the team assignment grades.***
  - *Rewarding exceptional team members and penalizing non-contributors helps avoid many of the conflicts and resentments that often occur when students work on group projects. A procedure for collecting ratings and using them to adjust team grades is described in the literature.*
- ***Anticipate problems and get help when necessary.***

Cooperative Learning / Distance Learning

- **Millis, B.J. "Managing—and Motivating!—Distance Learning Group Activities," http://www.tltgroup.org/gilbert/millis.htm**
- **Getting Set Up**
  - Ask yourself key questions about the proposed group activity
  - Be certain that group activities further the course objectives
  - Explain to students the nature and value of the proposed activities
  - Be certain to give clear instructions.
- **Provide students with a sense of closure.**
- **Forming Teams**
  - Keep the group size small
  - Unless there is a compelling reason to do otherwise, aim for heterogeneous groups
  - To ensure heterogeneity, form teacher-assigned teams.

Cooperative Learning / Distance Learning

- **Creating Team Learning Environments**
  - Keep groups together long enough to establish positive working relationships
  - Allow time for team building
  - Encourage students to monitor, as you will, group processing
  - Encourage students to practice and reinforce positive social skills.
- **Use Classroom Assessment Techniques (CATs) to determine student progress.**
- **Cooperative Learning Activity Structure**
  - Structure activities to promote positive interdependence
  - Promote individual accountability
- **Set up a clear, non-competitive, criterion-referenced grading scheme.**
- **Anticipate problems and don't be afraid to seek constructive help.**
- **Remember that the research on deep learning is unequivocal. To reach your intended educational outcomes, you must provide students with opportunities for interactions and for active learning. These should occur in carefully structured, sequenced activities that are frequently assessed.**

Cooperative Learning / Distance Learning

- West, M.L, and Luetkehans, L. "Ten Great Tips for Facilitating Virtual Learning Teams," http://www.psdcorp.com/dislearn.htm
- Tip #1 - Help team members manage "cyberstress" by helping them feel connected to the facilitator and other team members.
- Tip #2 - Plan frequent e-mail prompts to help team members overcome procrastination.
- Tip #3 – Provide a variety of tools to support the different phases of problem solving.
- Tip #4 – Assist team members when they struggle with achieving consensus.
- Tip #5 - Assemble teams strategically based on task and talent.

Cooperative Learning / Distance Learning

- **Tip #6 - Provide timely and meaningful feedback.**
- **Tip # 7 - Scaffold topical discussions using a threaded discussion (asynchronous) tool.**
- **Tip #8 - Encourage elaboration through questioning and hypertext linking.**
- **Tip #9 – Discourage judgment, criticism and personal attacks.**
- **Tip #10 – Intervene to highlight areas of common ground among conflicting team members.**

Team Exercise

- **Pick a class in your freshman sequence**
- **Design two different ACL student exercises for this class**
  - First exercise should take no more than 5 minutes total (for all parts)
  - Second exercise should take approximately 15 minutes for the students to complete and report out

Report out to the group

ACL References

- http://www.clcrc.com/
- http://www.active-learning-site.com
- http://www2.ncsu.edu/unity/lockers/users/f/felder/public/RMF.html
- http://foundationcoalition.org
- http://www.psu.edu/celt/clbib.html
- http://www.wcer.wisc.edu/nise/cl1/

Summary:
How do I know if it is ACL?

- ✓ **P**ositive Interdependence
- ✓ **I**ndividual Accountability
- ➢ **G**roup Processing
- ➢ **S**ocial Skills
- ✓ **Face**-To-Face Interaction