Principles for Classroom and Curricular Innovation

Jeff Froyd, Texas A&M University, froyd@ee.tamu.edu
David Cordes, University of Alabama, cordes@cs.ua.edu

Make a sheet of paper

+	Δ
Issue Bin Questions Comments	

Workshop Outline

- **1:30 PM -** Workshop Guidelines (5 min.)
- **1:35 PM –** How do people learn? (90 min.)
- **3:05 PM –** BREAK (15 minutes)
- **3:20 PM -** Active/Cooperative Learning (30)
- **3:50 PM -** Curriculum Integration (35 min.)
- **4:25 PM -** Technology-Enabled Learning (35)

Tenets of Learning

- **Each learner needs learning goals**
- **Each learner relates incoming information to his/her existing cognitive network**
- **Sharing and listening to the insights of others helps improve your understanding of workshop content**
- **Effective workshops are partnerships between facilitators and participants.**
  - Effective workshops do not occur when participants expect the facilitators to do all the cognitive work
  - Effective workshops do not occur when facilitators expect that participants will be able to “just make sense” out of a large set of informative slides
- **Each participant brings many mental models to learning and change experiences.**

Basic Guidelines

- **Will operate in a team-based mode**
  - The group knows more than any one person
- **Interrupt frequently**
  - No pre-defined set of material that “must” be covered in this workshop

Introduction: Team Formation

- **Self-Organize into four-person groups**
  - Want to emphasize diversity
    - Try to organize so that you have as little in common as possible on your team
  - Introduce yourselves (name & discipline) within the group

How do people learn?

Part One

90 minutes

Getting Started

- **As a team, construct a comprehensive exam question.**
  - Decide on the objective(s) of the question, i.e., what do expect that students should be able to do?
  - What "stuff" (data, information, knowledge, skills, wisdom) should the students know in order to be able to answer the question?
  - How might student learn the expected "stuff"?
  - How might you facilitate the expected student learning?

Part One: Overview

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

Pedagogical Approaches

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

Expectations: What do you want people to learn?

- Course syllabi
- Learning objectives
- Taxonomies
- Competency matrices
- Rubrics

Expectations: What do you want people to learn?

Current Reality: Where are learners starting from?

- Data about entering students
- Pre-tests
- Experience with past students

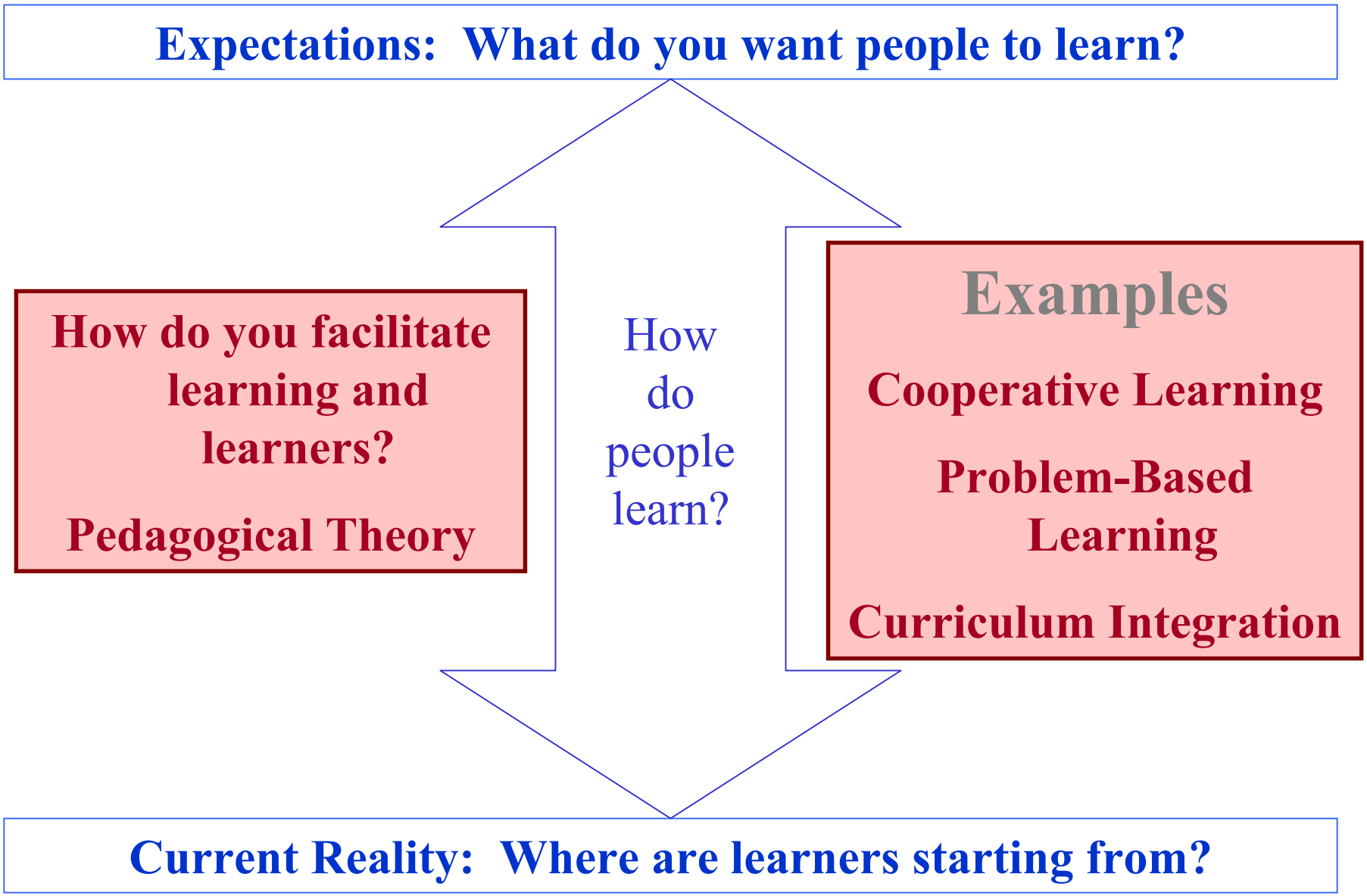
Expectations: What do you want people to learn?

How do people learn?

How do people close the gap?

Neurological
Cognitive
Conceptual
Classroom
Organizational

Current Reality: Where are learners starting from?

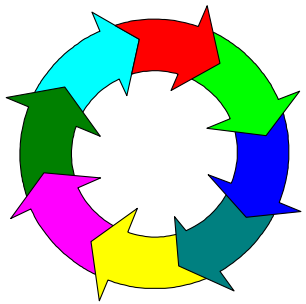

Expectations: What do you want people to learn?
How do you facilitate learning and learners?
Pedagogical Theory
How do people learn?
Examples
Cooperative Learning
Problem-Based Learning
Curriculum Integration
Current Reality: Where are learners starting from?

Expectations

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?

Four Questions

- **What do I want people to learn?**
  - Expectations, judgment
- **What do I want people to learn?**
  - Data, experience
- **How do people learn?**
  - Learning process
  - Research: neurology, psychology, cognitive science, artificial intelligence, physics education
- **How might I facilitate learning?**
  - Teaching process

Reflection Model for Learning and Teaching

Team Exercise

THINK-PAIR-SHARE

Identify two insights that you have gained from the four-question model for learning and teaching.

Identify two questions for which you would like answers.

Reflection
Model for Learning and Teaching

- Pedagogy and how we learn are separate
- Way the questions were organized
- Ways students learn and where they start are important
- Students change over time
- Importance of how people learn and little training for EVERYONE
- Focus on teacher as deliverer; issue is proper balance with other approaches
- Efficacy of teaching method
- Learning dependent on delivery technology
- Importance of starting point
- Being able to meet everyone's needs
- How do we develop techniques to get every learner where we want?
- What do learning obj have to contain?
- How do we balance learning and pedagogical theories?
- How do we teach with different starting points?
- How do you help students retain material?
- How do we adapt to students changing over time?
- How do people learn?

Question #1:
What do I want people to learn?

- **Answer #1: Course syllabi**
- **Answer #2: Learning objectives**
- **Answer #3: Taxonomies of learning**
- **Answer #4: 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

Expectations
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						

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

Expectations and Learning

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.

Information Dump: What is Blosser's Taxonomy?

- Cognitive Memory
  - recall, recapitulate, clarify
- Convergent Thinking
  - explain, draw conclusions, solve problems
- Divergent Thinking
  - elaborate, synthesize, generate alternatives
- Evaluative Thinking
  - rate, judge, select from set of alternatives, prioritize

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 / 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

Question #2
How do people learn?

- Neurological
- Cognitive
- Conceptual
- Classroom
- Organizational

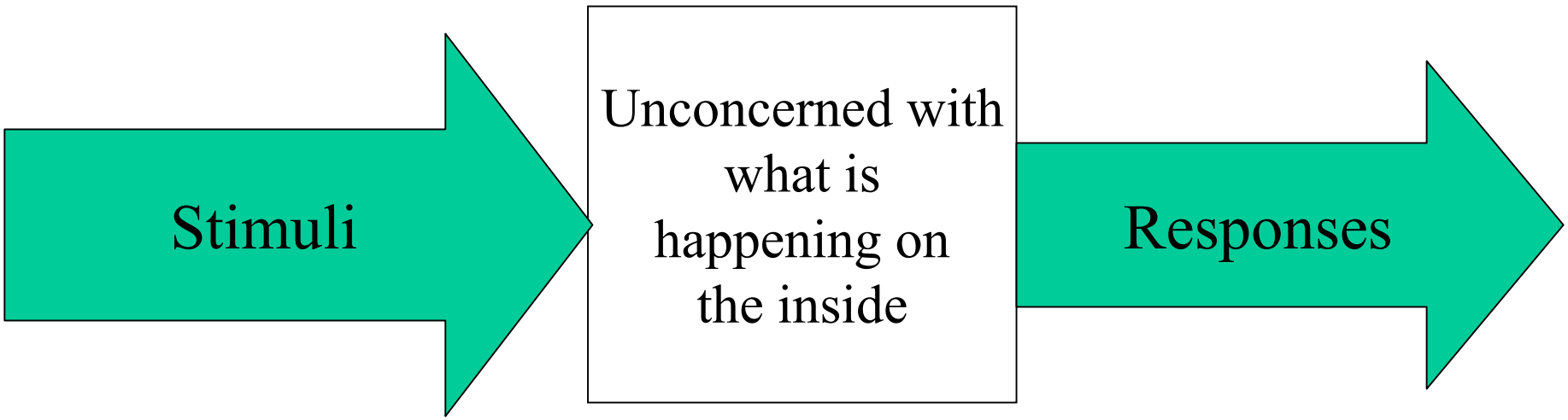
Question #2: How do people learn?

- **Neurological**
  - Connections of 10^{10} neurons, 10^{14} synapses
  - fNMR and PET scans indicates active parts of the brain for various tasks
  - Structure
    - Memory
      - Declarative vs. non-declarative
      - Short-term vs. long-term
    - Information Processing
    - Executive
  - Long-term memory requires protein synthesis

Question #2
How do people learn?

- **Cognitive**
  - Prior cognitive structures (video: Private Universe)
  - Staged intellectual development
    - Perry
    - Belenky
    - Ma??
  - Evolution of learning models
    - Behavioral
    - Cognitive, Phase I - Information Processing
    - Cognitive, Phase II – Metacognition
    - Cognitive, Phase III - Learner-centered

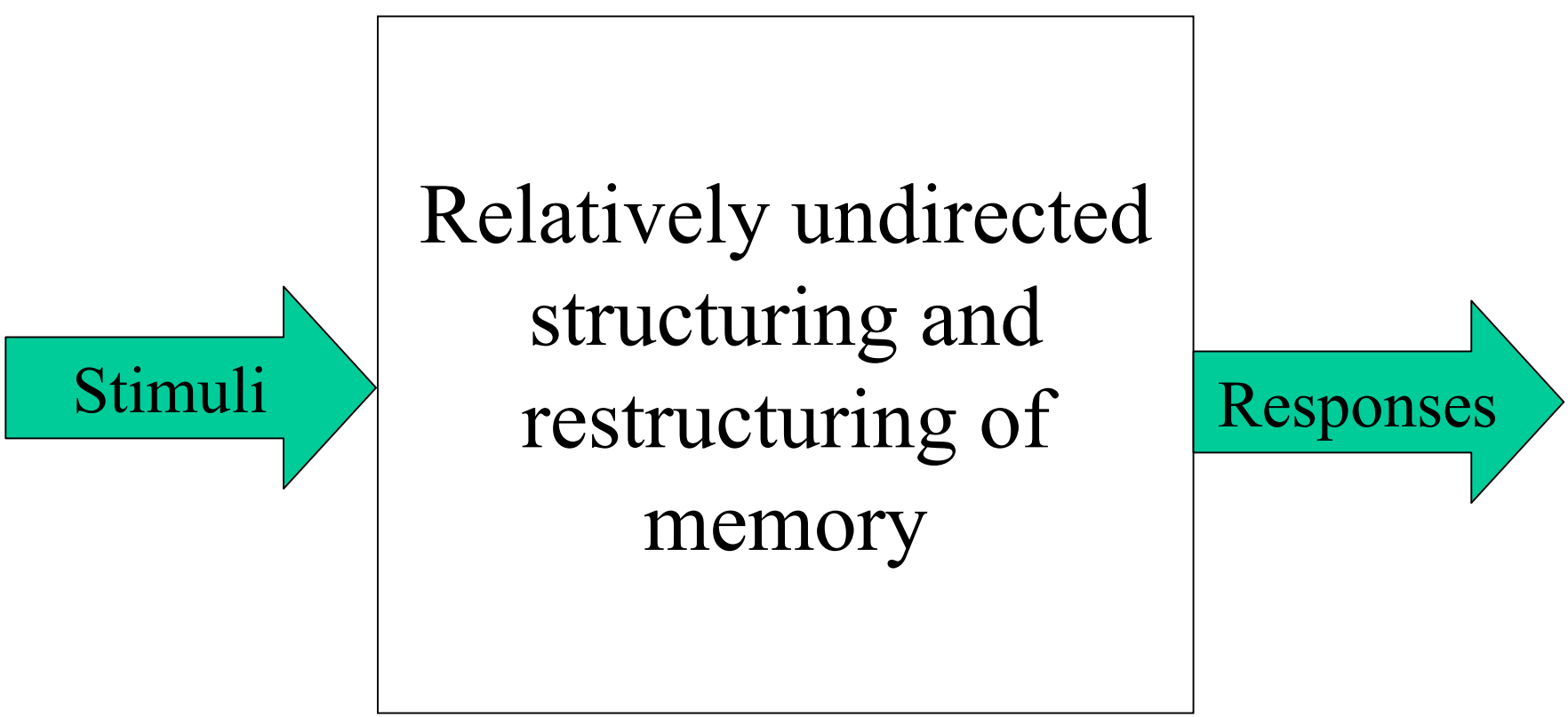
Behaviorist Model



Behaviorist Model

- **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**

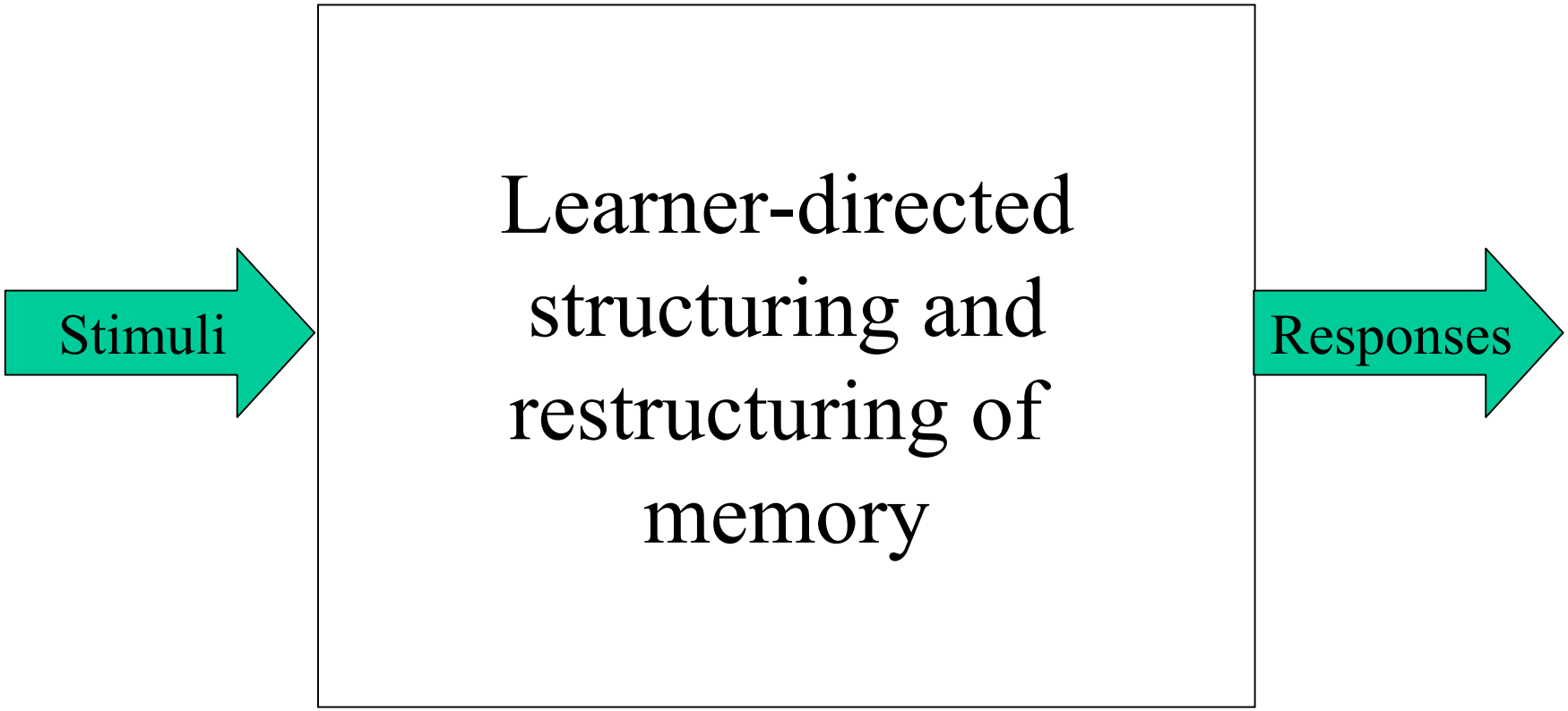
Cognitive Model, Phase I



Cognitive Model, Phase I Information Processing Model

- **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**

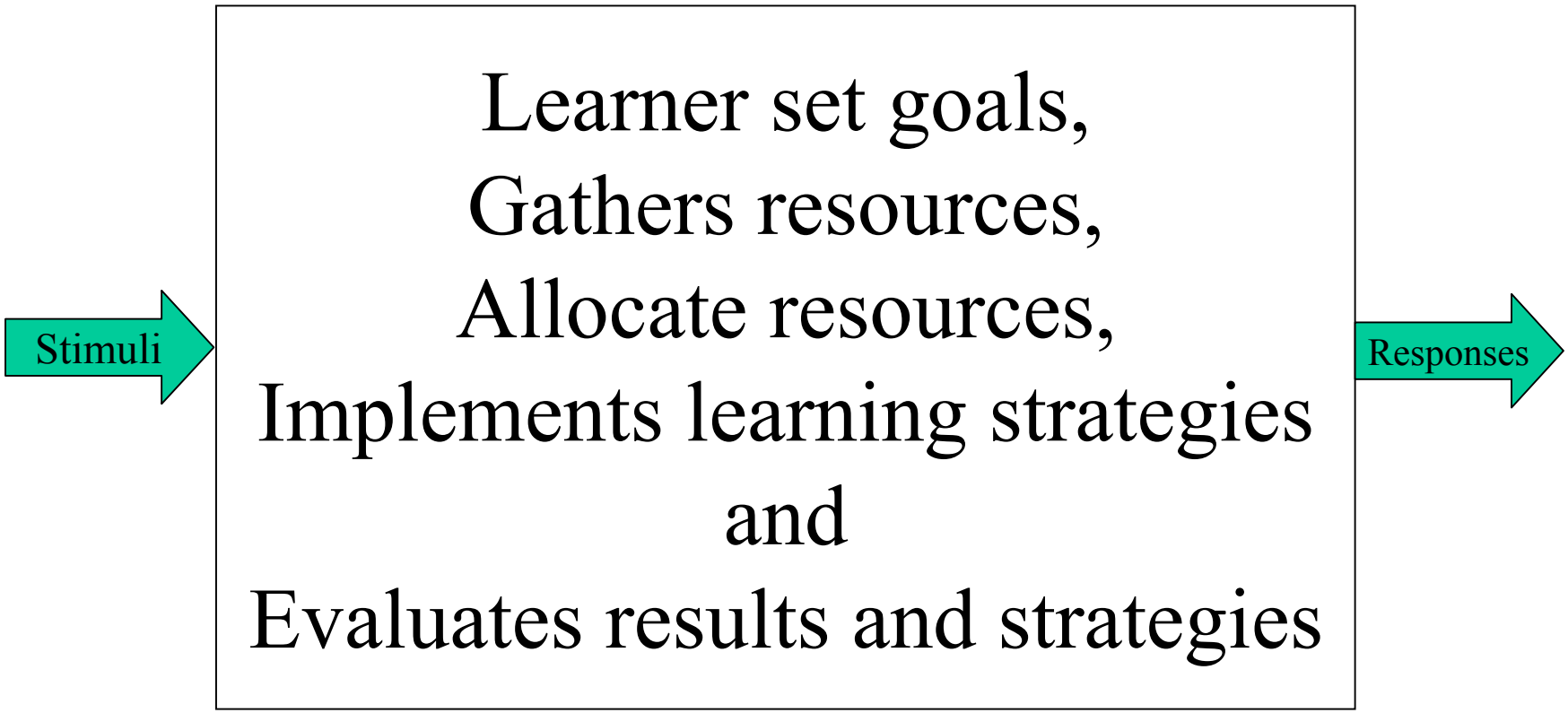
Cognitive Model, Phase II



Cognitive Model, Phase II Meta-cognition

- **Learning is learner-directed structuring and restructuring of memory directed by the learner, i.e., the learner thinks about thinking, meta-cognition.**
- **Instructional implications**
  - **Model thinking processes**
  - **Promote reflection, e.g., journals, descriptions of problem solving processes**
  - **Explicitly teach learning strategies**

Cognitive Model, Phase III



Cognitive Model, Phase III Learner-Centered Models

- **Learner sets goals, marshals resources, strategically allocates resources, and self-evaluates results and strategies.**
- **Instructional implications**
  - **Encourage transition to self-directed learning**
  - **Encourage learning in groups**
  - **Promote authentic problem solving**

Question 3:
How might I facilitate learning?

Team Exercise

Behavioral Model (Teams: 1, 5, 9, …)

How might you facilitate learning?

Information Processing Model (Teams: 2, 6, 10, …)

How might you facilitate learning?

Metacognition Model (Teams: 3, 7, 11, …)

How might you facilitate learning?

Learner-Centered Model (Teams: 4, 8, 12, …)

How might you facilitate learning?

Report out to group

Question 3:
How might I facilitate learning?

- *??*

Unique Learners

- **Variations among learners**
  - Level of prior knowledge
  - Styles of cognitive processing, e.g., serial vs. holistic learners
  - Personality variables
  - Learning strategies
  - Beliefs about learning and thinking

Motivation

- **Behaviorist perspective – reinforcement and punishment**
- **Basic cognitive perspective – motivation from feedback that indicated a mismatch between memory structure and "real world"**
- **Self-worth theory**
  - **Mistake motivates learner to determine cause and correct**
  - **Mistake motivates learner to identify mitigating circumstances**
  - **Mistake motivates learner to deny mistake**
  - **Mistake motivates learner to blame someone else**

Motivation

- **Expectancy-value theory**
  - Motivation depends on likelihood of success and value that learner places on the task
- **Goals and learning**
  - Motivation depends on difference between goal and current performance
  - Motivation increases when progress toward goal is perceived
  - Motivation is increase when others are perceived as making progress toward the goal
- **Attribution theory**
  - Motivation depends on learner's perception of causes for success and failure
  - If learner attributes success to luck or forces over which the learner has no control, then motivation is low.

Motivation

- **Goal orientation theory**
  - **Mastery goal orientation, e.g., learn the material well: tolerates risk taking, seeks corrective feedback**
  - **Performance goal orientation, e.g., get a good grade: intolerant of risk, seeks confirmatory feedback**
- **Self-determination theory**
  - **Motivation is increased as learners make their own choices about what and how to learn**
- **Intrinsic versus extrinsic motivation**

Question #2
How do people learn?

- **Conceptual**
  - Force Concept Inventory (FCI)
  - Example: diffusion, heat, electric current, light
    - Ontological Structures: Processes vs. Substances
  - Modeling Approach (ASU)
    - http://modeling.la.asu.edu/modeling.html

Question #2
How do people learn?

- **Classroom**
  - Is social interaction important to learning?
  - Social constructivism
- **Facilitation**
  - Active/cooperative/collaborative learning

Question #2
How do people learn?

- **Organizational**
  - How your students and your department address change?
  - Change and resistance

References

- Squire, Larry and Eric Kandel, *Memory: From Mind to Molecules*, New York, Scientific American Library, 1999
- Svinicki, M., "New Directions in Learning and Motivation," in M. Svinicki (ed.), *Teaching and Learning on the Edge of the Millennium: Building on What We Have Learned*, New Directions for Teaching and Learning, volume 80, Winter 1999, Jossey-Bass Publishers
- Theall, M. *Motivation from Within: Encouraging Faculty and Students to Excel*, New Directions for Teaching and Learning, no. 78, San Francisco: Jossey-Bass, 1999
- **Reiner, Slotta, Chi, Resnick, Naive Physics Reasoning: A Commitment to Substance-Based Conceptions, *Cognition and Instruction*, 18(1), 2000, 1-34**

Question 3:
How might I facilitate learning?

Question 3 will be addressed in the last three sections of the workshop

End of Session

- **15 minute break**

- **On your piece of paper**
  - One Plus (**+**) : something you liked
  - One Delta (Δ) : suggestion for improving the section

  - Any “issue bin” items that you feel still need to be resolved further

Active/Cooperative Learning

Part Two

30 minutes

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?

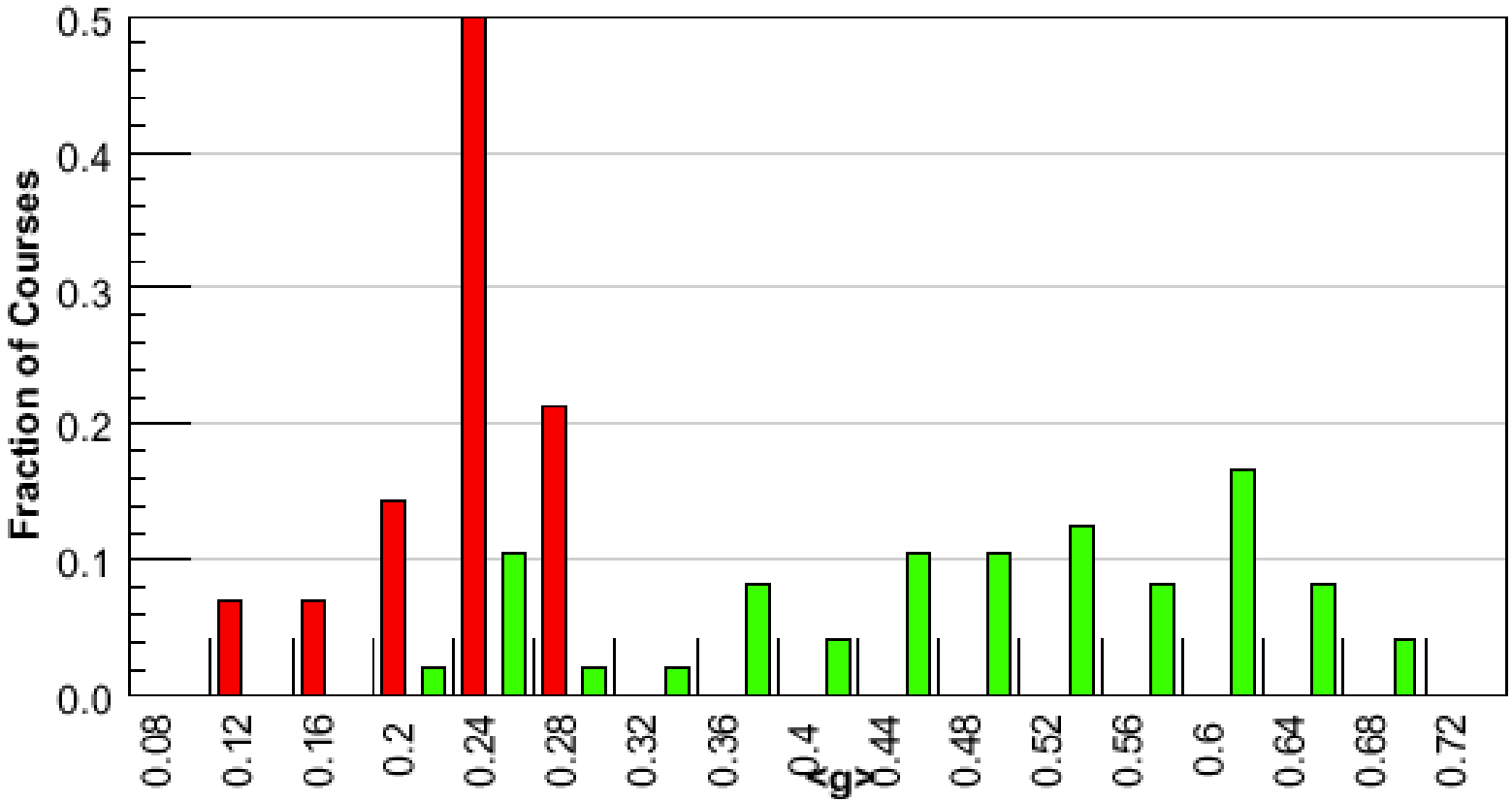
- **Cooperative Learning**
  - *Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning. Five essential components:*
    1. *clear positive interdependence between students*
    2. *face to face interaction*
    3. *individual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

Introduction to ACL

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?



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

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

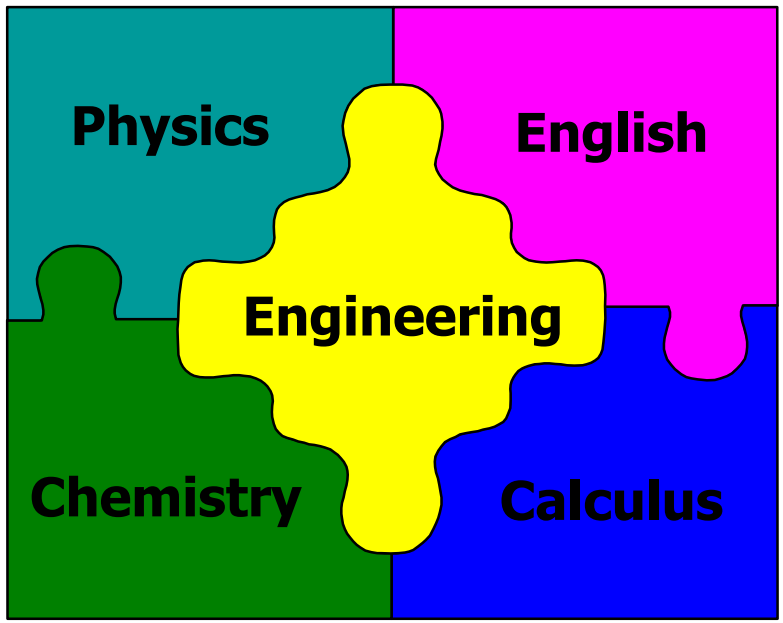
ACL References

- 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
- ✓ **F**ace-To-Face Interaction

Curriculum Integration



Part Three
35 minutes

Concept

- To help students build a small set of powerful concepts/abilities/skills instead of a large set of relatively weak concepts/abilities/skills
- To help students build connections across disciplines

Team Exercise

THINK • PAIR • SHARE

- **Describe at least two advantages for the students of restructuring a curriculum to emphasize a smaller set of more powerful concepts/abilities/skills.**
- **Describe at least two obstacles that would be encountered in attempting to create such a curriculum.**

Examples

- Six Ideas That Shaped Physics
- Conservation and Accounting Framework
- Mathematical Ideas
- Electronic Materials/Electromagnetics

Six Ideas That Shaped Physics

- **Conservation Laws Constrain Interactions**
- **The Laws of Physics are Universal**
- **The Laws of Physics are Frame-Independent**
- **Electromagnetic Fields are Dynamic**
- **Matter Behaves Like Waves**
- **Some Processes are Irreversible**

http://www.physics.pomona.edu/sixideas/

Conservation and Accounting Framework

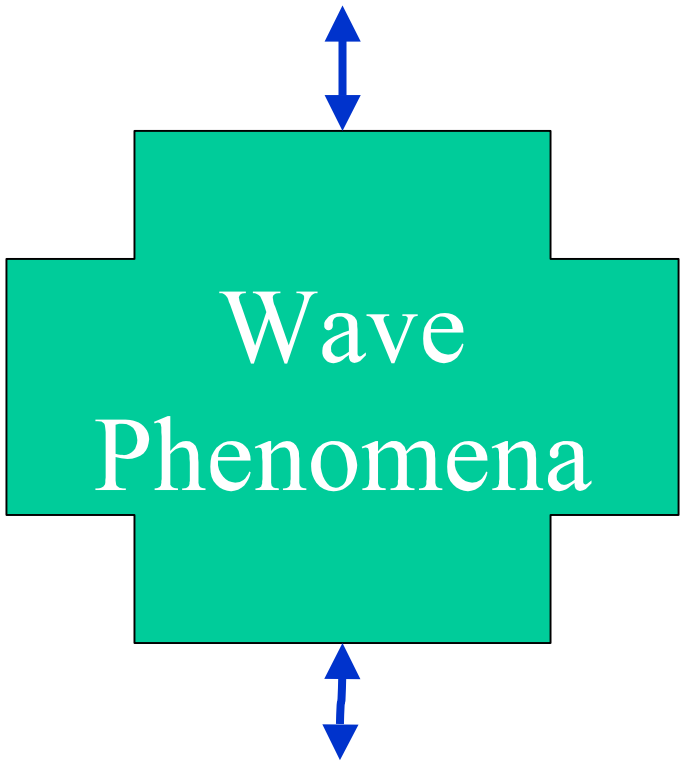
Restructure engineering science courses around the following concepts.

- **System Concept**
- **Extensive Properties**
- **Time**
- **Conserved Properties**
- **Accounting Principle**

Engineering science curricula built around these ideas are being offered at TAMU and RHIT.

Arizona State University

Properties of Electronic Materials



Electromagnetic Engineering

Arizona State University

- Implementation of the pair courses at ASU has been done several times.
- To measure the change in student learning, the faculty members created a Waves Concept Inventory (WCI).
- Students who participated in the paired courses showed more improvement on the WCI inventory compared to students who participated in the traditional courses.

Mathematical Ideas

- **Measurement**
- **Measurement in the presence of structure**
- **Equivalence and equivalence classes**
- **Transform**
  - go somewhere else, do something, return

Gary Sherman, Professor of Mathematics

Rose-Hulman Institute of Technology

First-Year Science, Engineering, and Mathematics

First-year curricula in science, engineering and mathematics could be based around the following concepts.

- **Rate of change**
- **Accumulation**
- **Conservation and Accounting Framework**
- **Materials**

Team Exercise

Develop at least broad two underlying concepts (different than the ones that have been presented) one of the following.

- Biological ideas for engineering
- Nanotechnology
- Information Technology
- Invent your own area

Integrated Activities

Examples

Technology-Enabled Learning

Part Four
35 minutes

Overview

- **Introduction: What is technology-enabled learning?**
  - 10 minutes
- **What have others done?**
  - 25 minutes
  - I'm anticipating an very lively interaction.

Technology-Enabled Learning

In describing technology-enabled learning, I'm encouraging us to look at what the students do.

Technology-Enabled Learning

- **Consumptive Technology**
  - Students access and consume information.
  - Examples
    - Distance learning
    - Web sites

Technology-Enabled Learning

- **Collaborative Technology**
  - Students communicate and/or collaborate with other people: students, faculty members, industry representatives, etc.
  - Examples
    - E-mail
    - Web forums

Technology-Enabled Learning

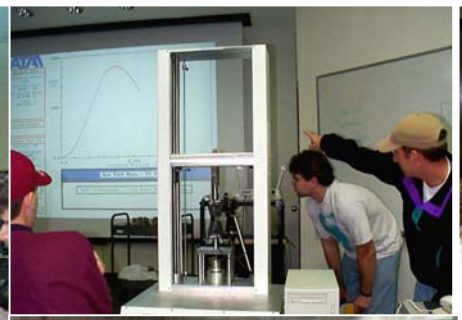
- **Generative Technology**
  - Students use technology to change the way they work.
  - Examples
    - Computer algebra, e.g., Maple, Mathematica
    - CAD Packages, e.g., AutoCAD, Cadence
    - Simulation Packages, e.g., SIMULINK
    - Computational Packages, e.g., MATLAB
  - Focus of the Foundation Coalition

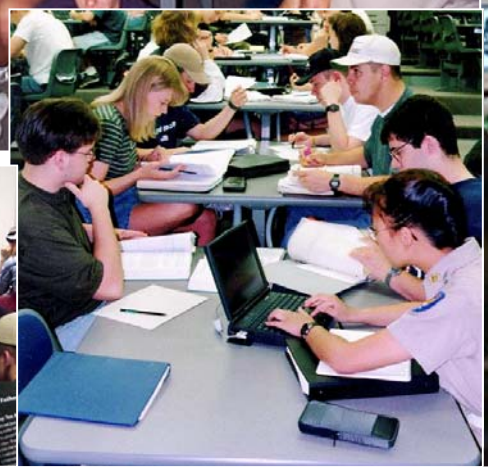
Part 2: What have others done?

Short information dump

- **Background Information**
  - One-page introduction to technology-enabled learning
- **Representative Foundation Coalition efforts**
  - Rose-Hulman Institute of Technology
  - Texas A&M University
  - University of Alabama
- **Another sample initiative**
  - RPI Studio Laboratories

New Classroom Environments





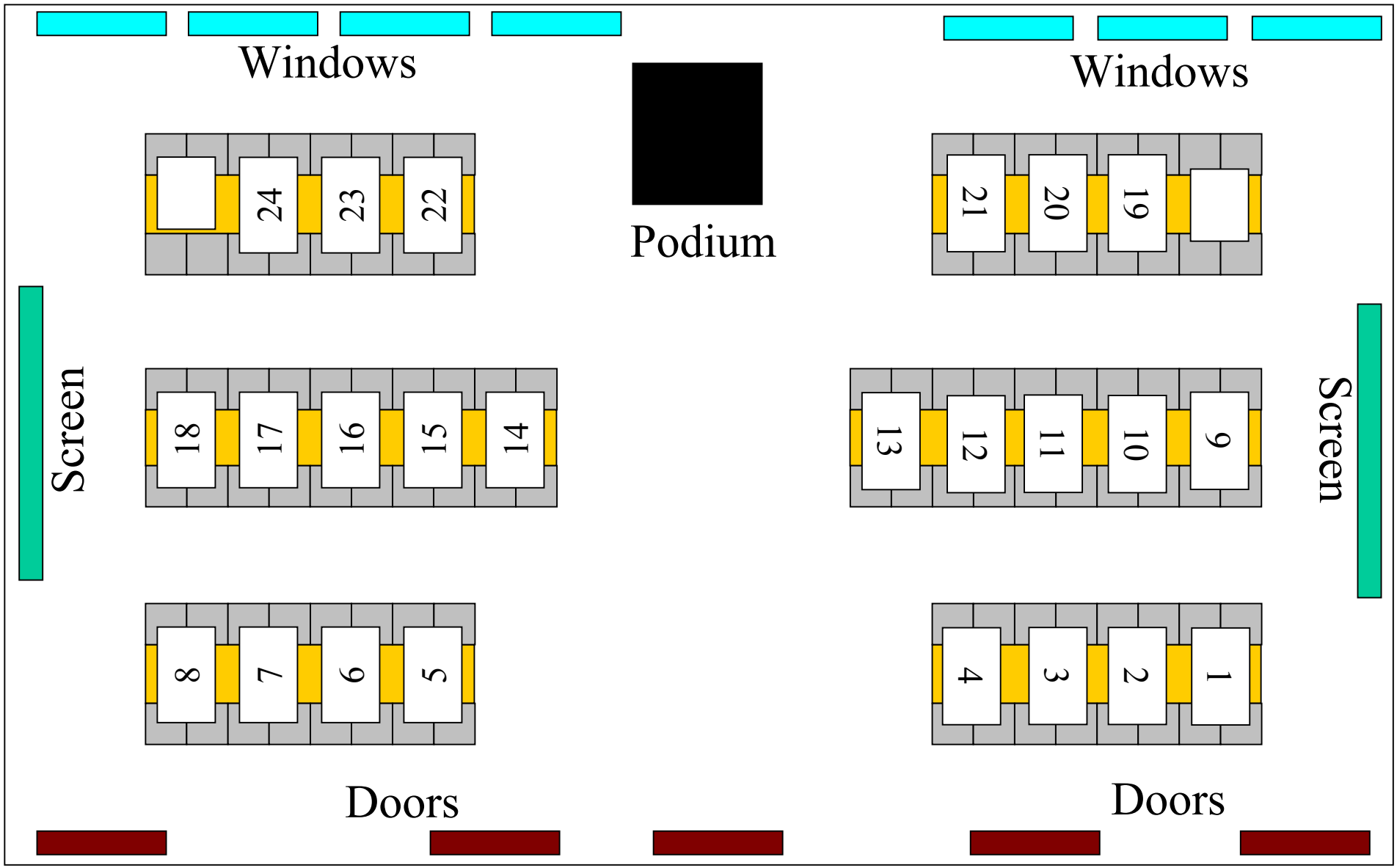
Rose-Hulman Institute of Tech

- **Philosophy**
  - Completely networked campus environment
- **Classroom layout & equipment**
  - Every student purchases a notebook computer as an entering student (model is specified by institution)
  - Over 20 classrooms have been equipped with network and power connections to support notebook computers
- **Software & Applications**
  - Maple (calculus), Working Model & Maple (dynamics), Physics labs (Excel - data acquisition/analysis)
- **Audience**
  - All engineering students and classes

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



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, FORTRAN, Maple
- **Audience**
  - Freshman engineering students
  - All students in introductory computing sequence

Alabama Classroom Layout

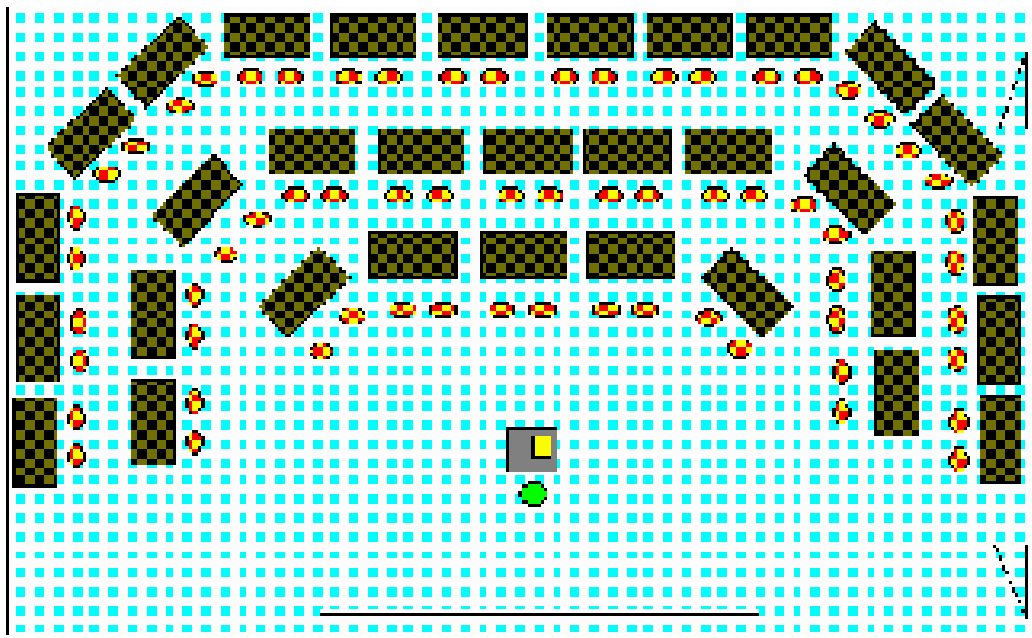
- **Several classroom formats exist**
  - All have computers at student desks, instructor console, projection system
  - Primarily used for lower-division classes

Rensselaer Polytechnic Institute (RPI) Studio Classrooms

- **Philosophy – studio environment**
  - Integrate classroom (lecture) with laboratory (experiments, acquire/display/analyze data)
- **Classroom layout & equipment**
  - Tables with two students (one computer)
  - Student
    - Using computer faces ***away*** from instructor
    - Listens to lecture facing ***away*** from computer
- **Audience**
  - Mathematics, sciences, engineering students

RPI Classroom Layout

- **Students face instructor during lecture**
  - Away from computers
- **Student away from instructor when using computers**
  - Instructor can see monitors easily



End of Workshop

- **On the wall on your way out**
  - One Plus (**+**) : something you liked
  - One Delta (Δ) : something that we can improve
  - Any “issue bin” items that you feel still need to be resolved further