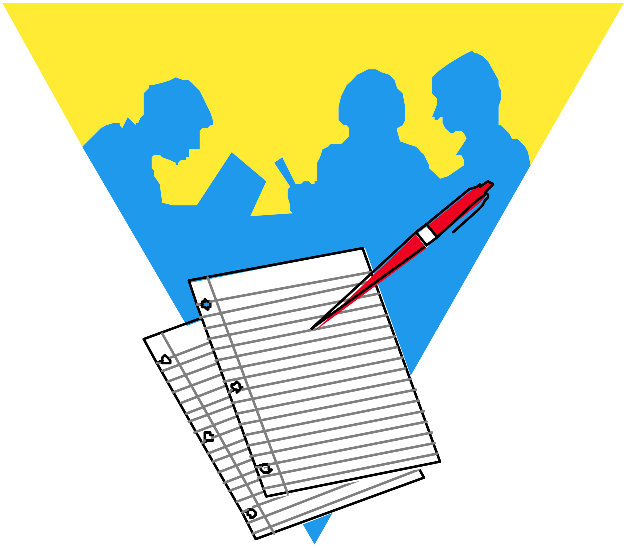
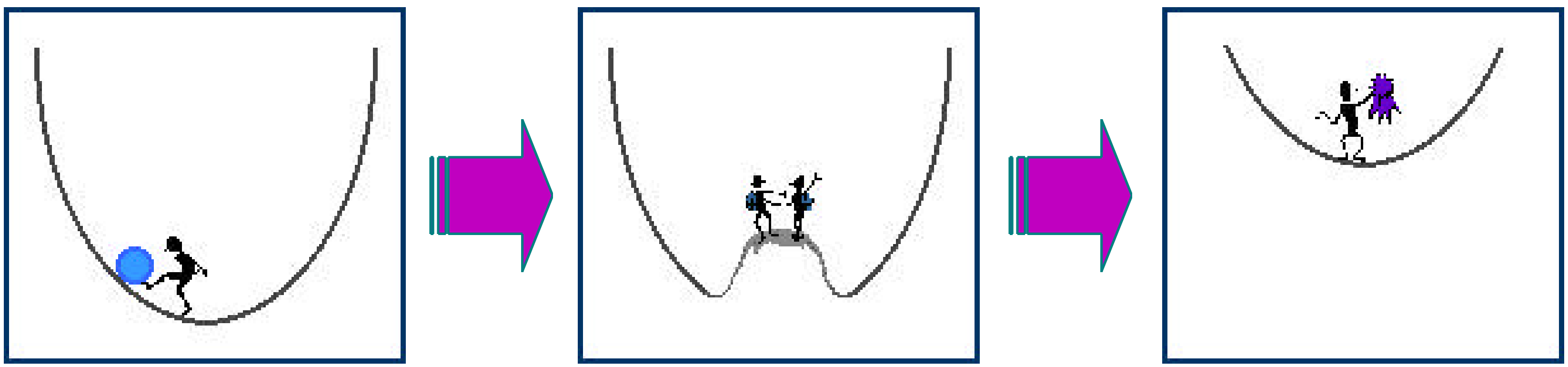
Reform in the Traditional Format



Kenneth Heller
School of Physics and Astronomy
University of Minnesota

University Instruction



Stable
Traditional

Meta-stable

Stable
Research-based Curriculum and Instruction

Outline

1. **What's Traditional**
   - A Little History
2. **What's Reform**
   - Instructional Models Based on Research
3. **Examples That Fit With Traditional Format**
   - Cooperative Group Problem Solving (Minnesota)
   - Tutorials (Washington, Maryland)
   - Peer Instruction (Harvard)
   - Overview Case Studies (Ohio State)
   - Interactive Demonstrations (Oregon, Tufts)
   - Socratic Dialog Labs (Indiana)
4. **Do They Help Student Achievement?**

University Tradition in USA

Lecture Recitation Section Laboratory Textbook

1700's - Education for Elite (Leaders)
Recitation Section and Textbook - Education is challenge
Taught by young graduate before a real job

1800's - Education for "Common" Person (Upper Class)
Recitation Section and Textbook
Lecture with Demonstrations Added - Education is "broadening"
Taught by a Professor
Laboratories Begin

1900's - Education for a Profession (Middle Class)
Lecture, Recitation, Lab, and Text - Education is serious
Instruction based on Behaviorism

2000's - Education for Elite (Everyone is elite) - Education is necessary
Advanced instructional theories based on research

Instructional Paradigms

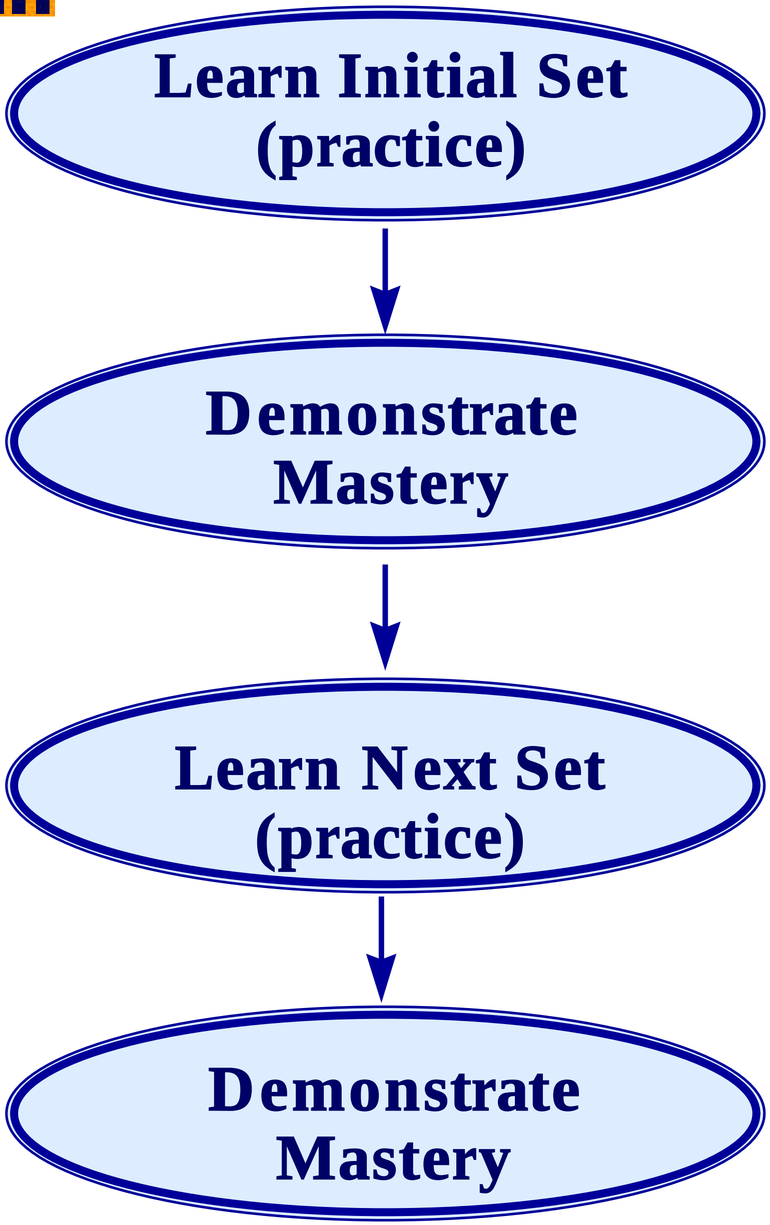
Instructional Paradigm	Expert-Novice Distinction	Key Mechanism of Transformation
Behavior	Different amounts of knowledge	Incrementation
Developmental	Qualitative differences in models (personal theories and explanations)	Perturbation
Apprenticeship	Qualitative differences in models and practice	Acculturation

F. Farnham-Diggory
Review of Educational Research, 64(3): 464-477

“Traditional Instruction”

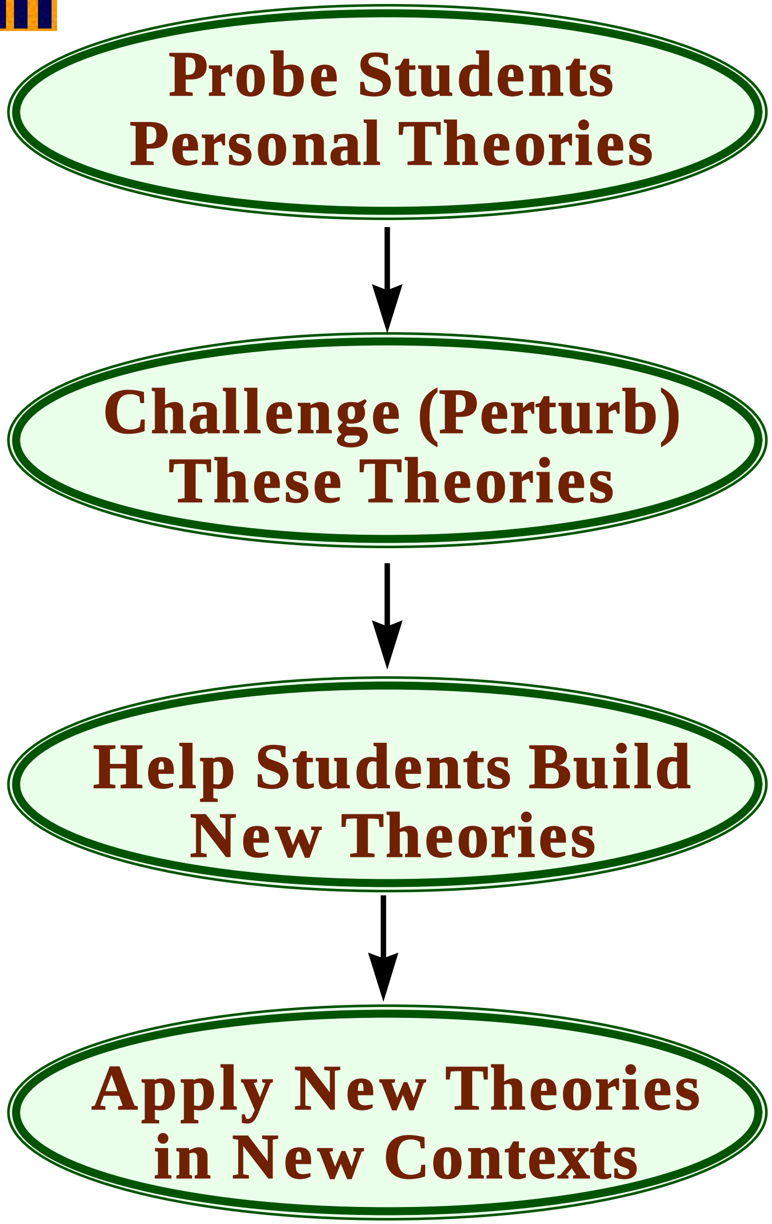
Behavior Paradigm

Edward Thorndike (1910)



- everyone can learn from simple, logical steps (supplied by experts in the field)
- incrementation
- examples of only the “essentials”

Knowledge Acquisition



Development Paradigm

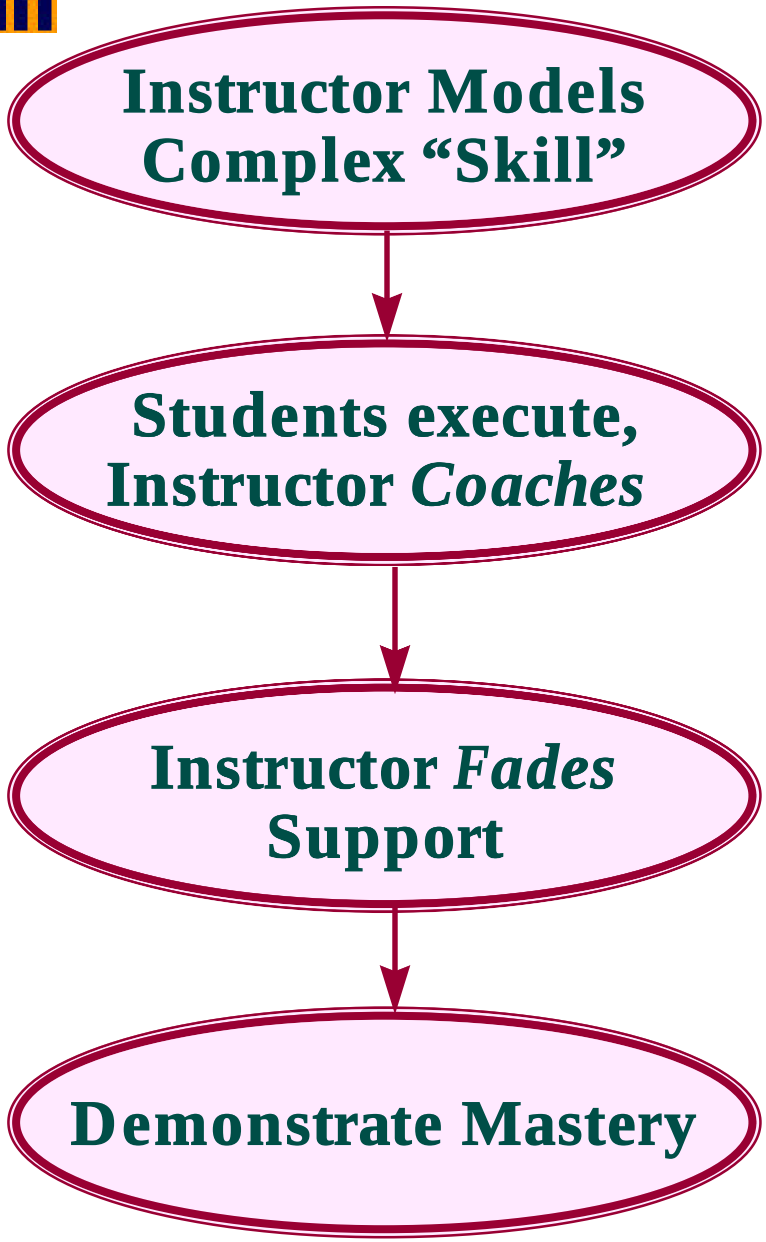
Jean Piaget (1950)

- **Most students have similar personal theories** (supplied by research)
- **Directly challenge personal theories**
- **All students must go through the same "quantized" stages** (supplied by research)

Knowledge Deletion & Acquisition

Cognitive Apprenticeship Paradigm

Collins, Brown, & Newman (1990)



Knowledge Use & Acquisition

- Student personal theories are interlinked by experience
- Desired behavior explicitly demonstrated in context
- Students practice desired behavior in context with coaching
- Personal theories changed as necessary

Research-based Curriculum & Instruction

"Constructivist"

Conceptual Understanding Research → **Developmental**

Expert-novice Research → **Apprenticeship**

Developmental: Arrange Context to Illustrate Specific Concept

Apprenticeship: Highlight Specific Concept Within a General Context

Techniques

Developmental:
- Challenge "Misconceptions"
- Guided Discovery
- Apply New Knowledge

Apprenticeship:
- Model
- Coach
- Fade

**Students come to a course with a personal theory of physics.
Course gets them to modify it**

Roots of Research-based Instructional Models

Developmental

Tutorials
(McDermott & Group, Washington)

Interactive Lecture Demonstrations
(Thorton & Sokoloff, Tufts & Oregon)

Peer Instruction
(Mazur, Harvard)

SDI Labs
(Hake, Indiana)

Apprenticeship

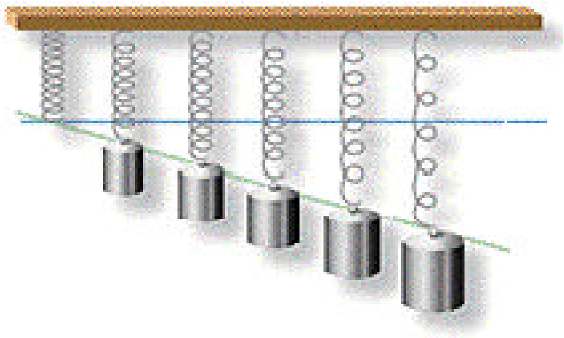
Cooperative Group Problem Solving
(Heller & Heller, Minnesota)

Overview, Case Study
(Van Heuvelen, Ohio State)

Tutorials

Emphasis: Physics Concepts

Task design based on misconception research

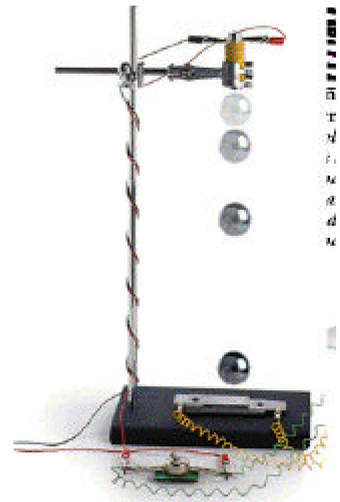


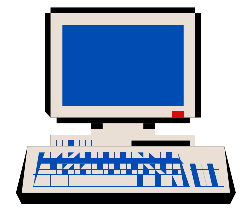
Replace Recitation Section

- **1 Hour/week**
- **Content in time with a standard lecture, laboratory**
- **Pretest to identify difficulties**
- **Students work in groups of 3-4**
- **Worksheets with structured questions about a simple activity**
  - **Clash of observation with student preconceptions**
  - **Guided inquiry for students into forming next stage concept**

COACHING Concept Construction (instructor & peer)

Interactive Lecture Demonstration





Emphasis: Physics Concepts

Task design based on misconception research

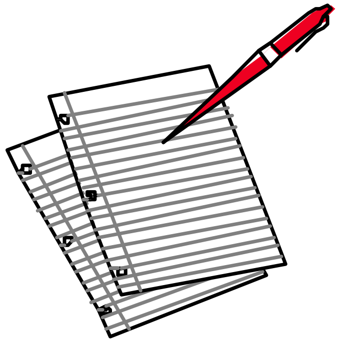
Integrate into Lectures

- **Demonstrations which clash with student preconceptions**
- **Computer data acquisition and display for instant feedback**

MODELING Concept Construction

Peer Instruction

Emphasis: Physics Concepts



Questions based on misconception research

Modify Lecture Style

- **Students complete short reading quiz**
- **Lectures on concepts periodically stopped to ask a conceptual question**
- **Questions clash with student preconceptions**
- **Students informally discuss questions**
- **Based on responses, lecturer guides students to next stage concept**

MODELING Concept Construction

COACHING (peer)

Suppose you want to ride your mountain bike up a steep hill. Two paths lead from the base to the top, one twice as long as the other. Compared to the average force you would exert if you took the short path, the average force you exert along the longer path is

1. four times as small.

2. three times as small.

3. half as small.

4. the same.

5. undetermined—it depends on the time taken.

Peer Instruction
Mazur

A hydrogen atom is composed of a nucleus containing a single proton, about which a single electron orbits. The electric force be-tween the two particles is 2.3 x 10 39 greater than the gravitational force! If we can adjust the distance between the two particles, can we find a separation at which the electric and gravitational forces are equal?

1. Yes, we must move the particles farther apart.

2. Yes, we must move the particles closer together.

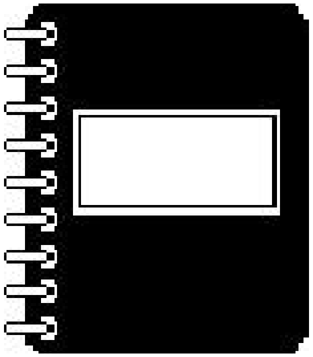
3. no, at any distance

Peer Instruction
Mazur

Overview Case Study

Emphasis: Physics Concepts and Problem Solving

Questions based on misconception research.
Explicit Problem-solving strategy



Modify Lecture Style

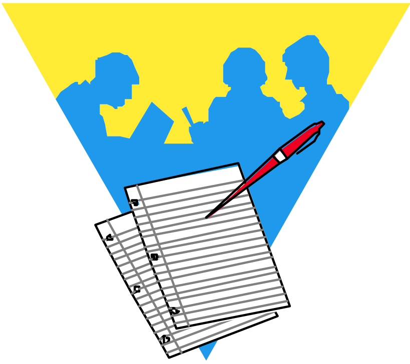
* **Three-step treatment of topics**
  - ❶ **Conceptual Overview**
  - ❷ **Quantitative Exposition**
  - ❸ **Case Studies (More Complex Problems)**
* **Pause lectures for informal group tasks (conceptual or problem solving)**

MODELING: **Concept Construction, Problem Solving**

COACHING: **study guide, peer**

Socratic Dialog Instruction

Emphasis: Physics Concepts



Exercises based on expert procedures for qualitative representation of concepts

Replace Laboratory

- **Exercises with real objects for illustration**
- **Incremental practice to achieve expert-like behavior**
- **Worksheets with questions about a simple activity**
  - **Guide students into forming next stage concept**

COACHING: Concept Construction (instructor &peer)

Cooperative Group Problem Solving

Physics in a Culture of Expert Practice
Solving "Real" Problems

Emphasis: Problem Solving

- Problem design based on expert-novice research
- Explicit problem-solving strategy

Modify Lecture Style, Recitation and Laboratory

* Lectures: **MODEL** concept construction in problem context, and expert problem solving
* Recitation and Laboratory: **COACH** expert-like problem solving in structured cooperative groups
  - context-rich problems that require physics decisions
  - problem-solving strategy
* Homework and Tests: **FADE** support for individual expert-like problem solving

Explicit Problem-solving Framework

Used by experts in all fields

STEP #1 — **Recognize the Problem**

What's going on?

STEP #2 — **Describe the problem in terms of the field**

What does this have to do with ...... ?

STEP #3 — **Plan a solution**

How do I get out of this?

STEP #4 — **Execute the plan**

Let's get an answer

STEP #5 — **Evaluate the solution**

Can this be true?

Not Context - rich

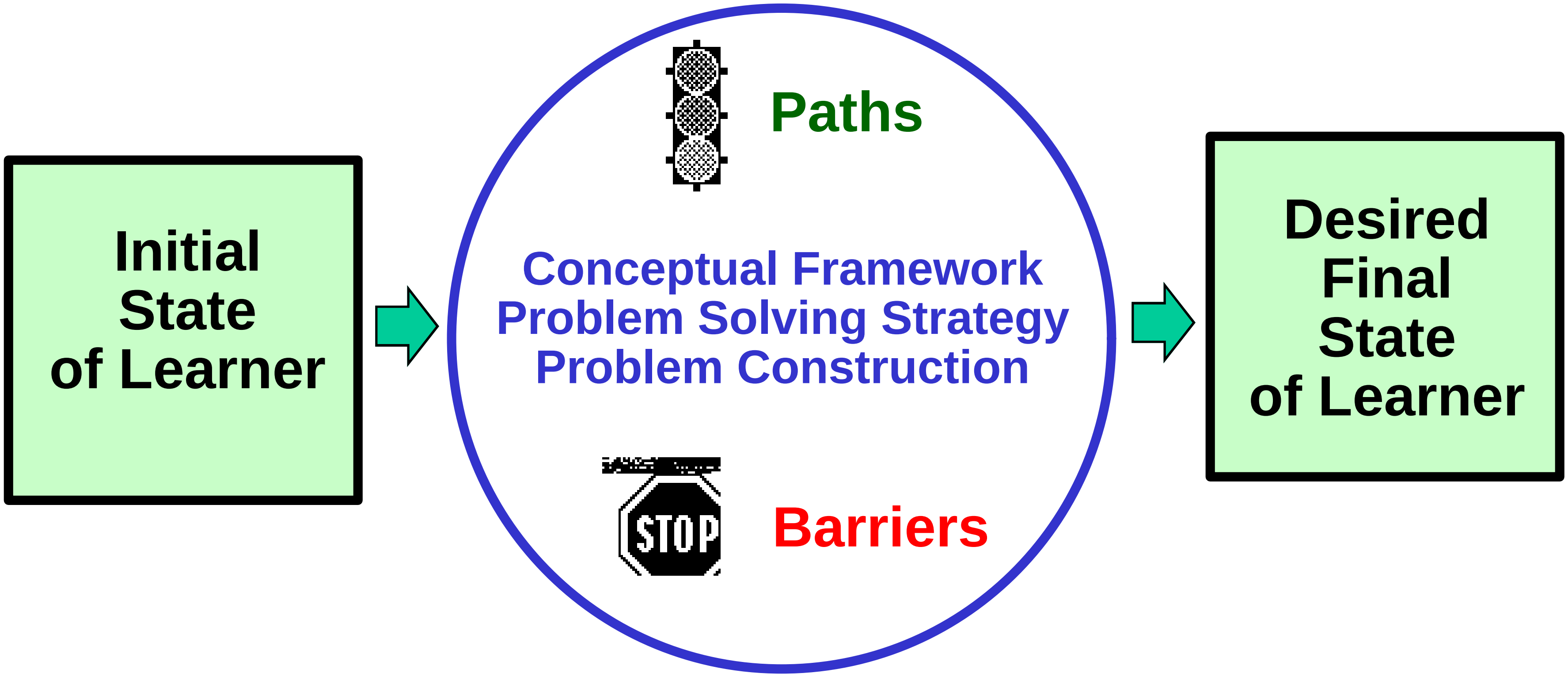
An infinitely long cylinder of radius R carries a uniform (volume) charge density r. Calculate the field everywhere inside the cylinder.

Chap 24, prob. 24, Fishbane, Gasiorowicz, Thornton

Context - rich

You have a summer job in a research laboratory investigating the possibility of producing power from fusion. The device being designed confines a hot gas of positively charged ions, called a plasma, in a very long cylinder with a radius of 2.0 cm. The charge density of the plasma in the cylinder is 6.0×10^{-5} C/m^3. Positively charged Tritium ions are to be injected into the plasma perpendicular to the axis of the cylinder in a direction toward the center of the cylinder. Your job is to determine the speed that a Tritium ion should have when it enters the cylinder so that its velocity is zero when it reaches the axis of the cylinder. Tritium is an isotope of Hydrogen with one proton and two neutrons. You look up the charge of a proton and mass of the tritium in your trusty Physics text and find it to be 1.6×10^{-19} C and 5.0×10^{-27} Kg.

Procedure for Change

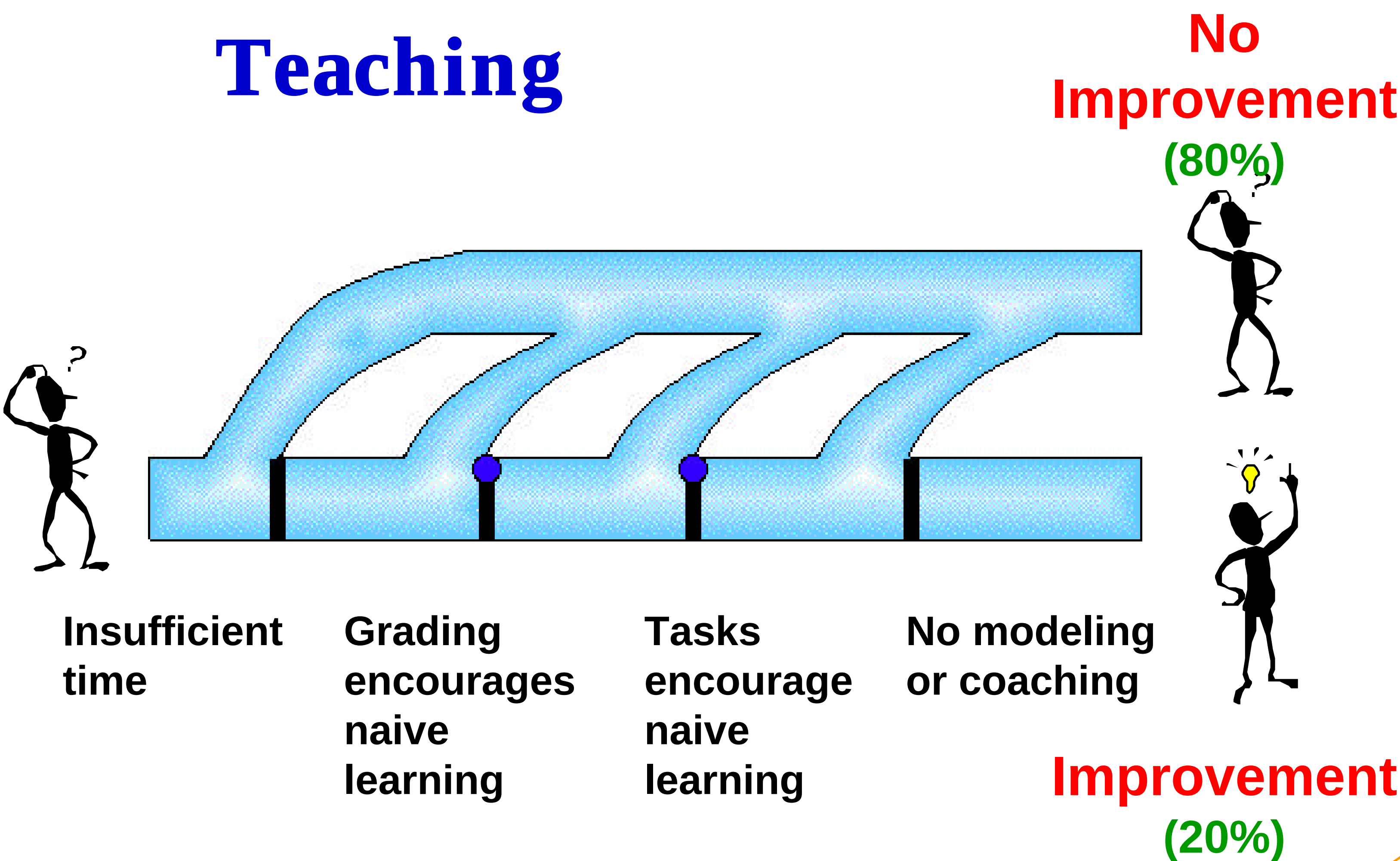


Transformation Process

F. Reif (1986)
Phys. Today 39

Teaching as Paths and Barriers

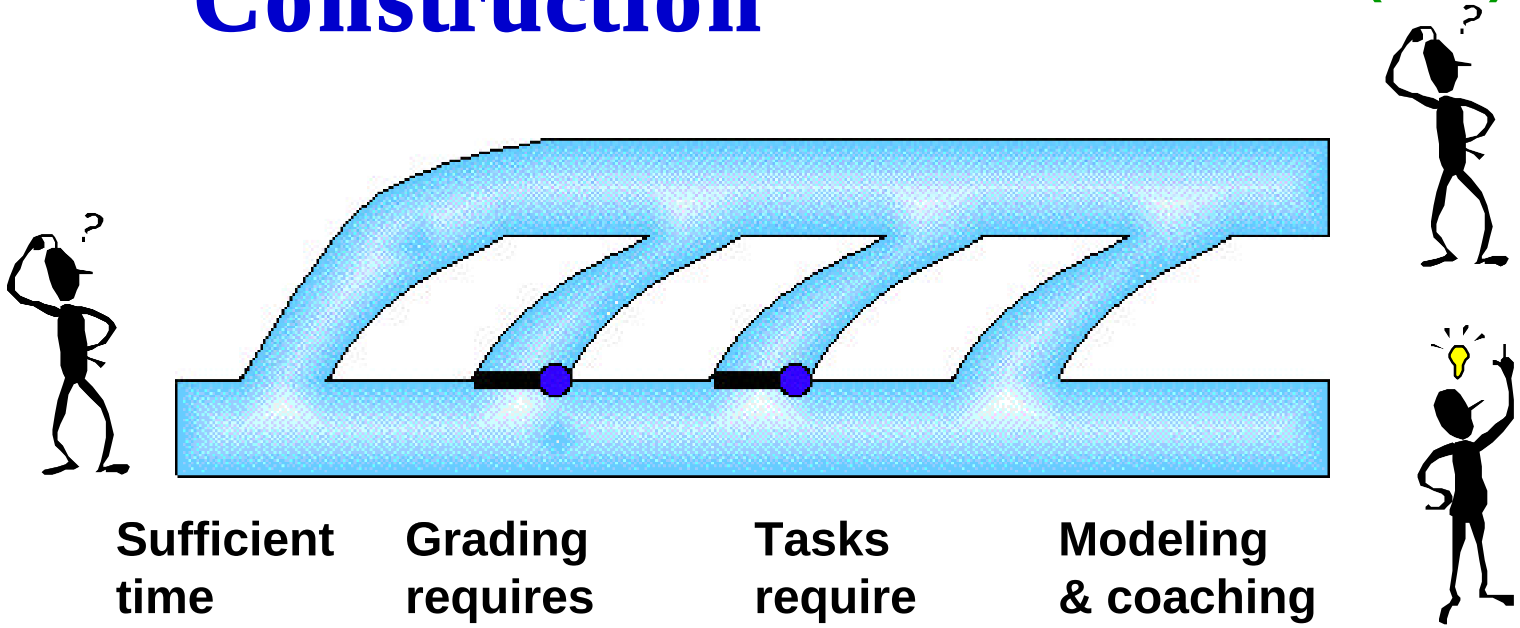
Traditional Teaching



Teaching as Paths and Barriers

Explicit Teaching for Knowledge Construction

No Improvement
(30%)



Sufficient time

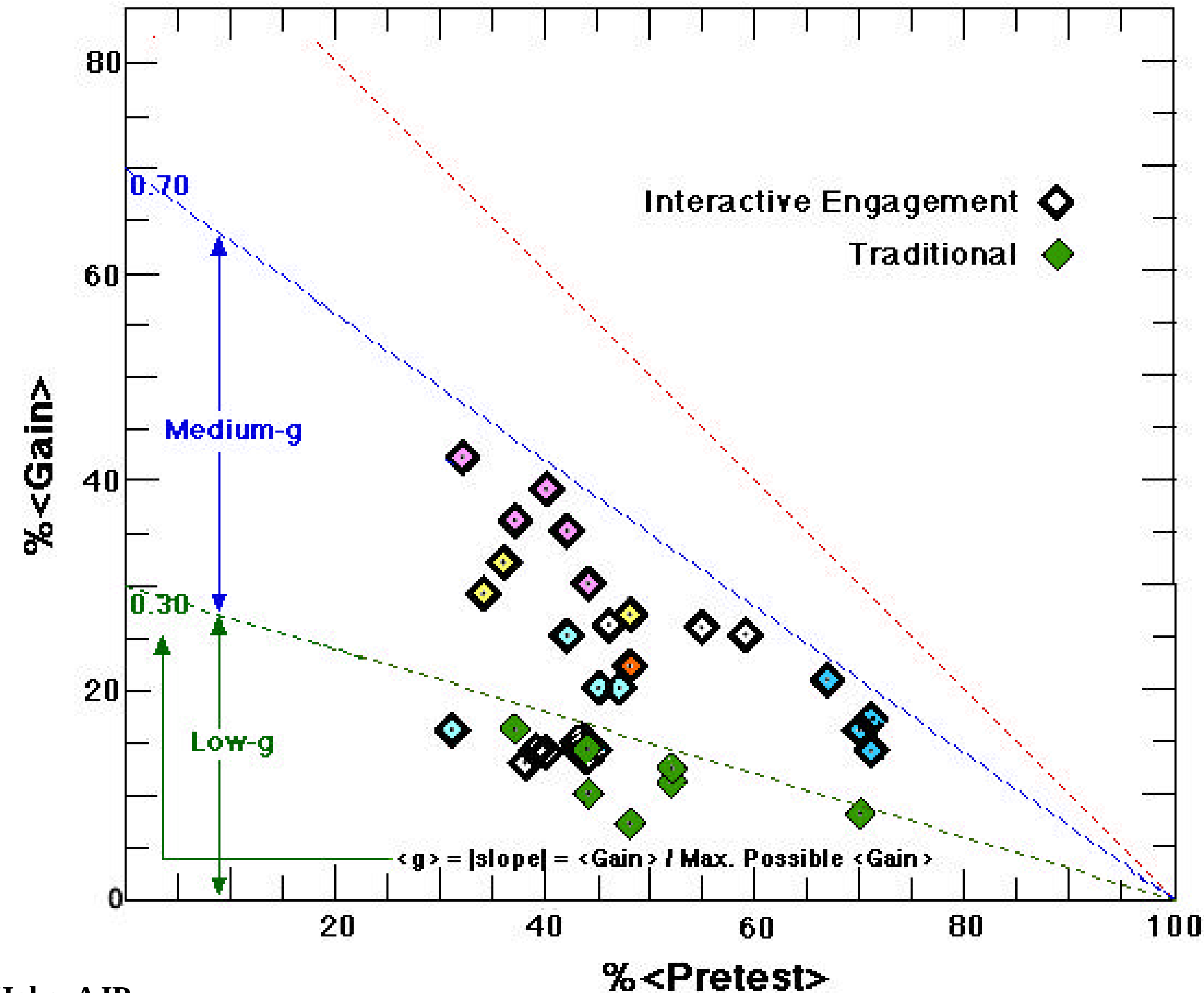
Grading requires knowledge construction

Tasks require knowledge construction

Modeling & coaching

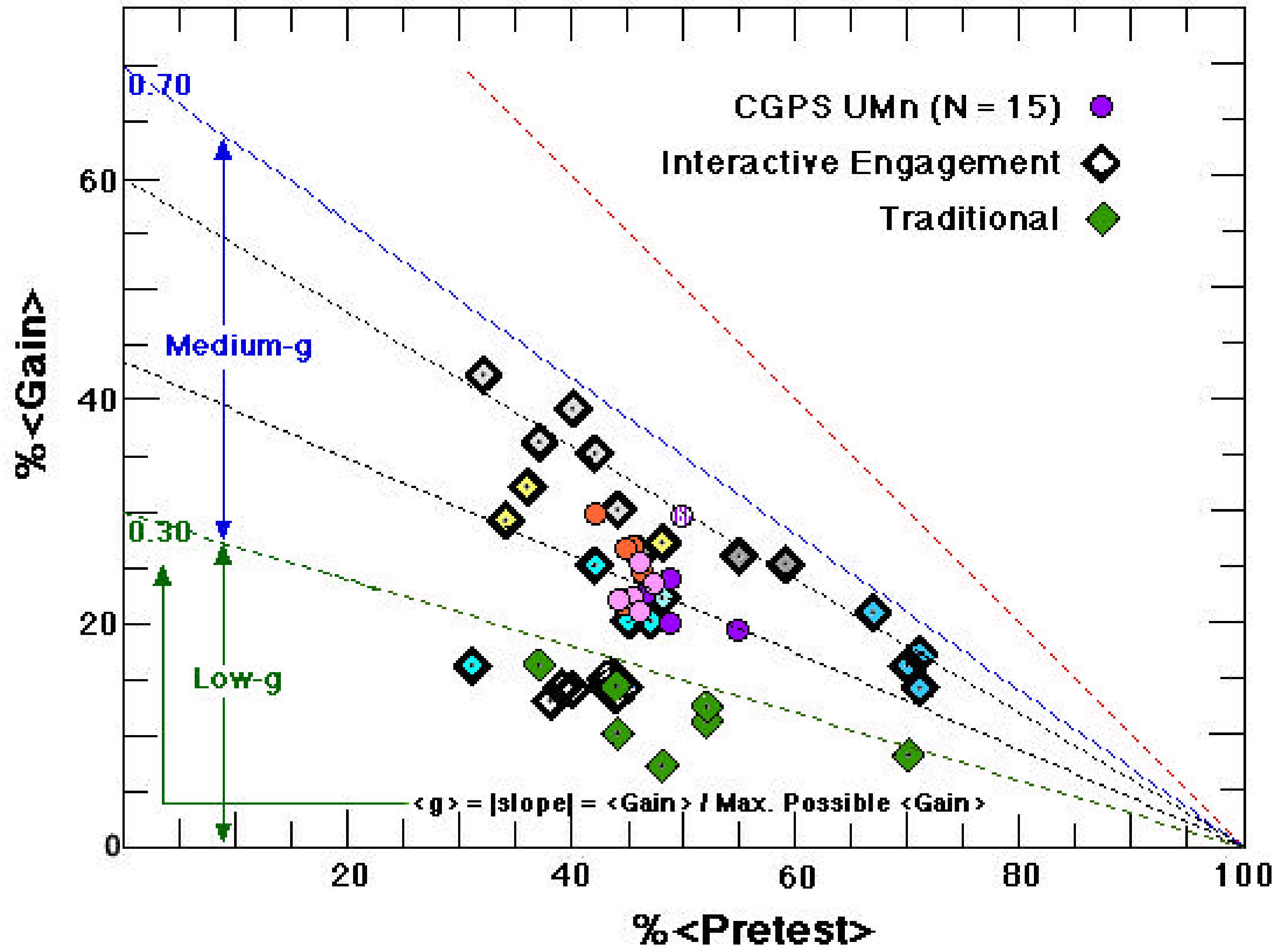
Improvement
(70%)

FCI Gains -- Universities

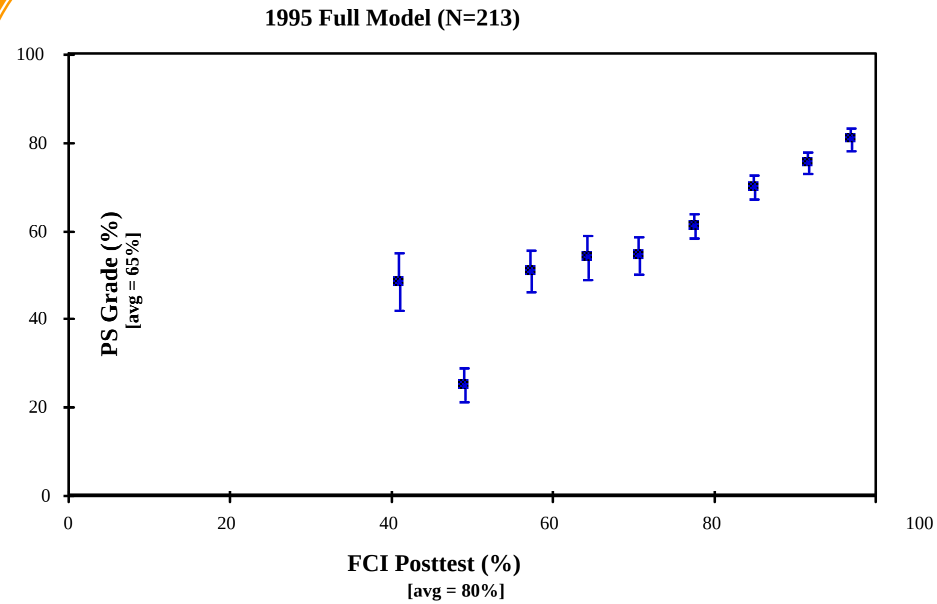


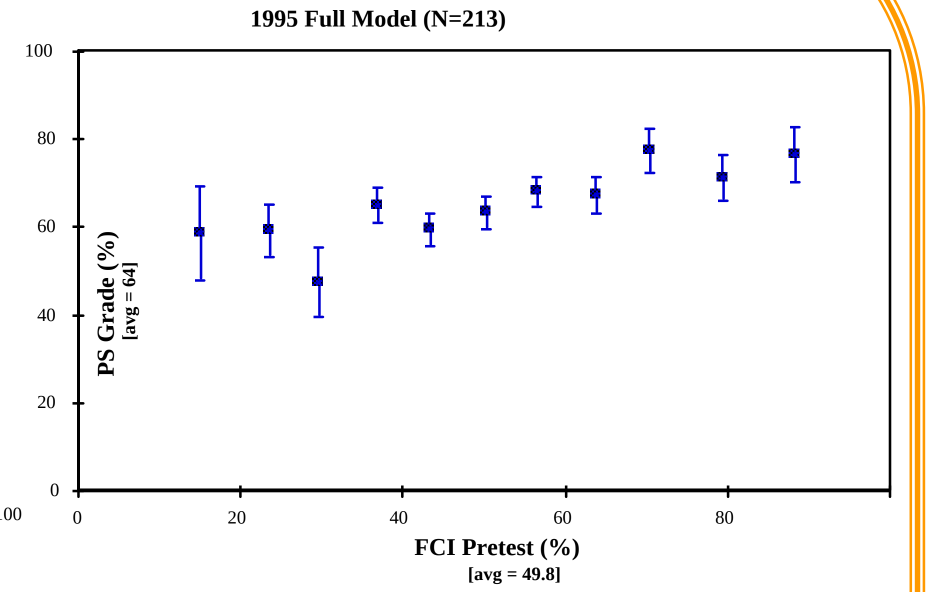
R. Hake, AJP

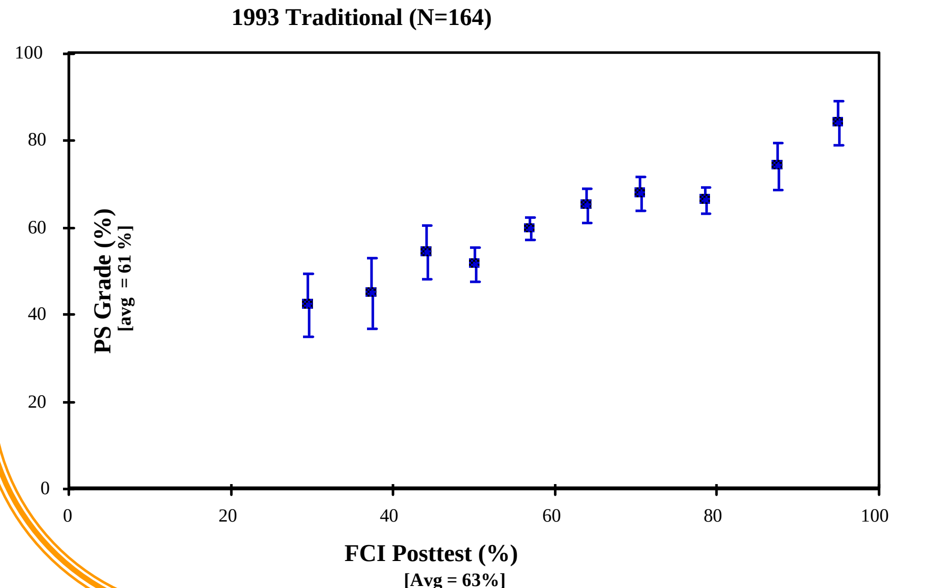
FCI Gains -- Universities

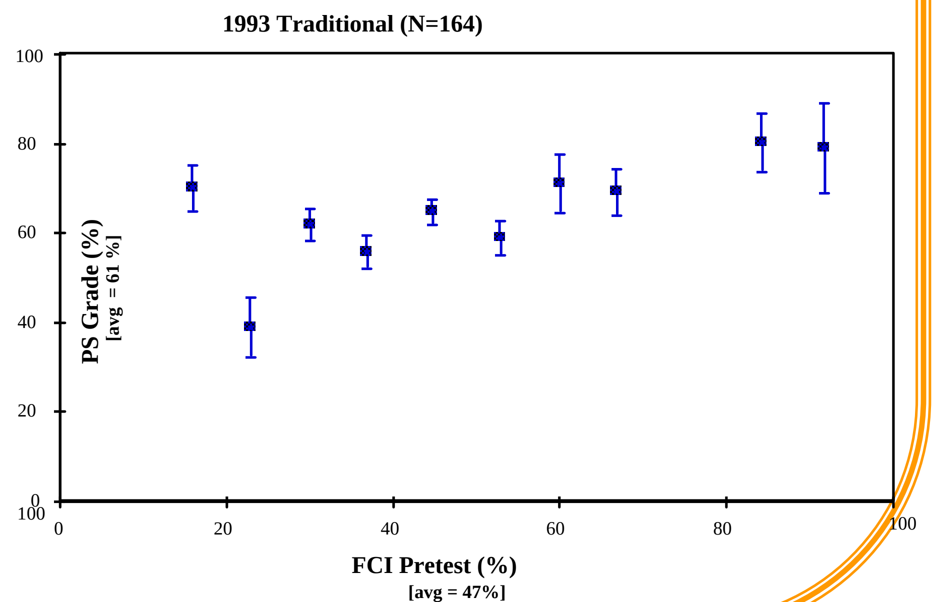


FCI and Problem Solving

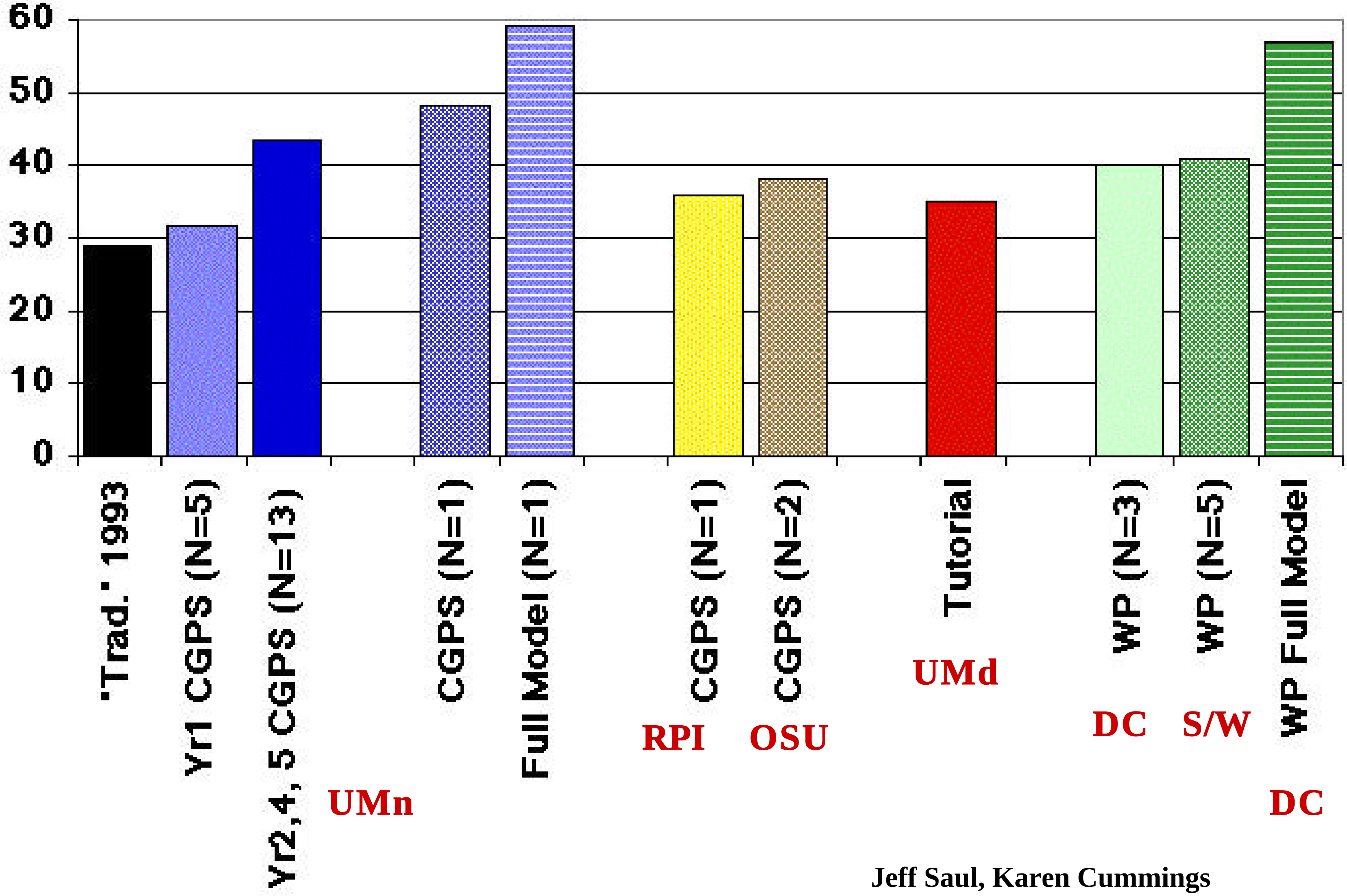






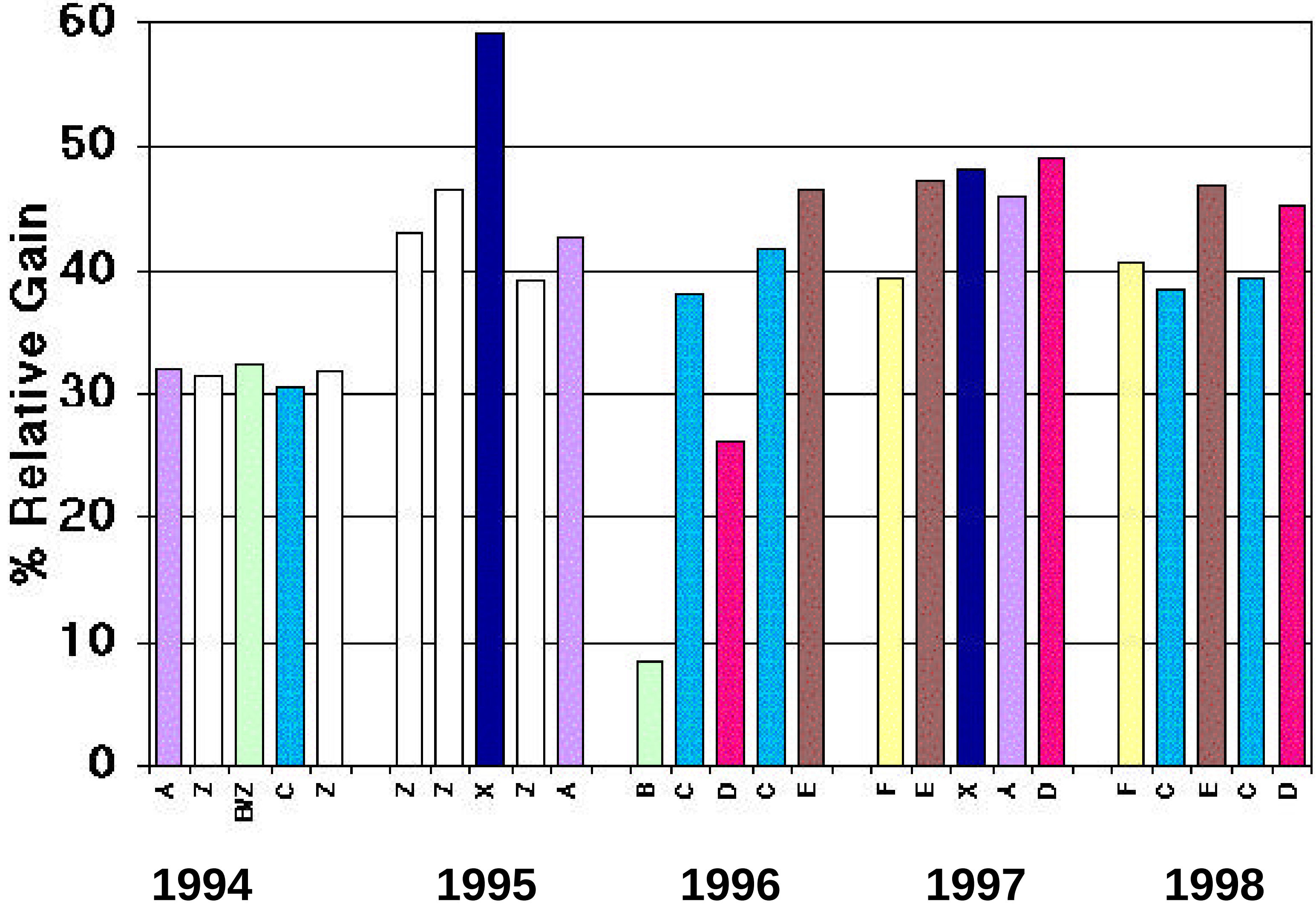


Comparisons of Full and Partial Models



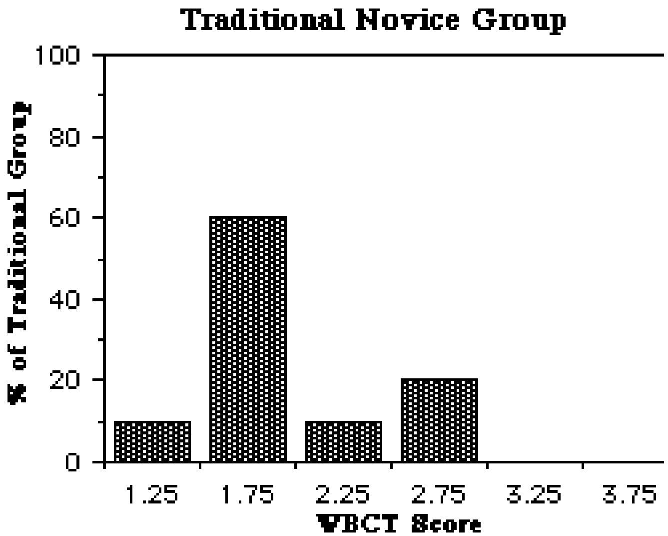
Jeff Saul, Karen Cummings

How Stable is Faculty Implementation of CGPS?

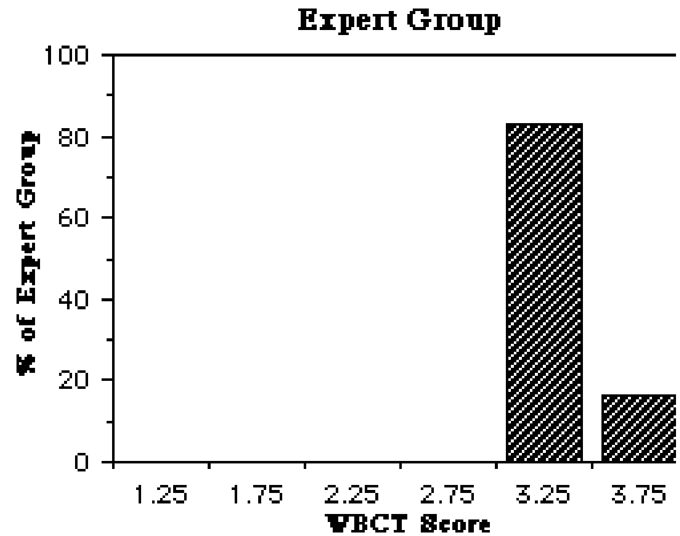


University of Minnesota Faculty

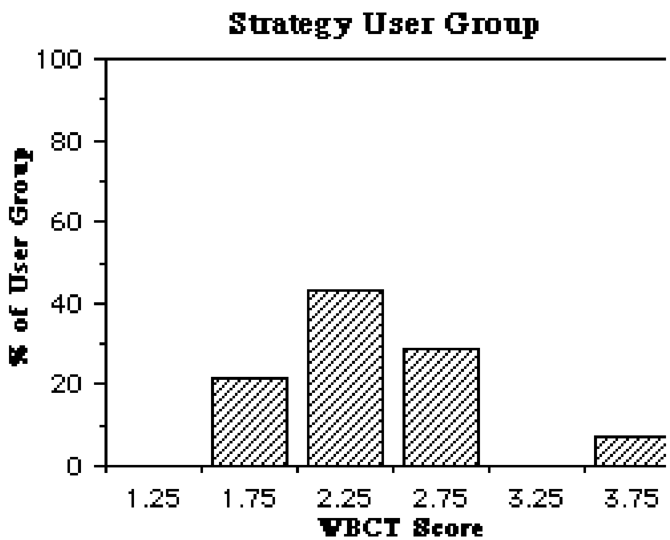
Hierarchical Organization of Knowledge



(b)

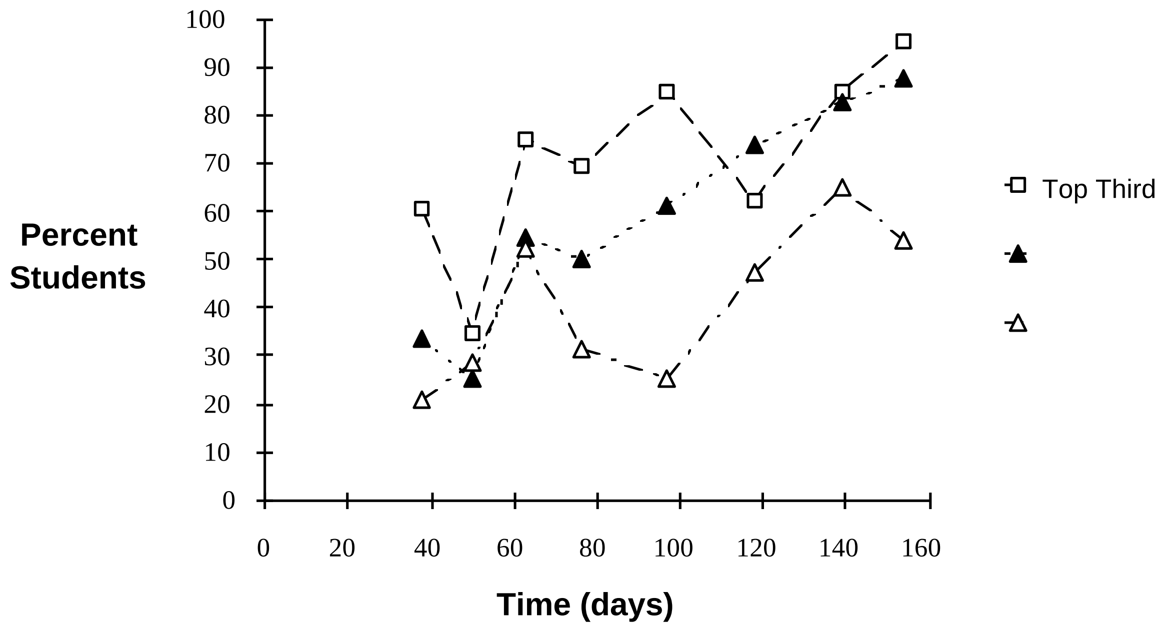


(a)



(c)

Improvement in Problem Solving
(algebra-based course)



Research Based Teaching Techniques in Traditional Structures

Raise the Ground State

Changing Content using Traditional Techniques

Shared Personal Innovations

Research-based Curriculum and Instruction