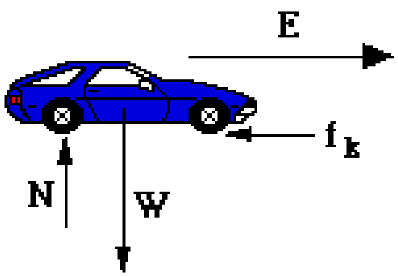
Cooperative Group Problem Solving – Learning Content by Solving Problems



$$\sum F = ma$$
$$f_k = \mu N$$
$$W = mg$$

"I understand the concepts, I just can't solve the problems."

Ken Heller & Qing Xu

School of Physics and Astronomy

University of Minnesota

20 year continuing project to improve undergraduate education with contributions by:
Many faculty and graduate students of U of M Physics Department
In collaboration with U of M Physics Education Group

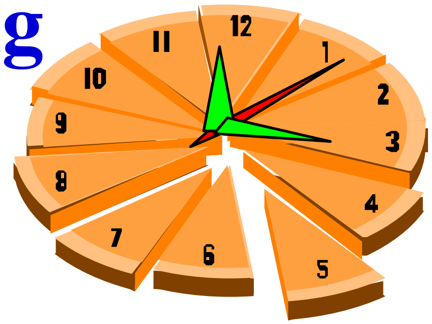
Details at http://groups.physics.umn.edu/physed/

Supported in part by Department of Education (FIPSE), NSF, and the University of Minnesota

Cooperative Group Problem Solving

Goals, Motivation, and Procedure

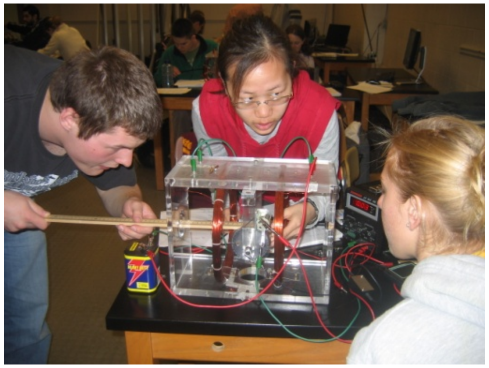
A Guide for Discussion



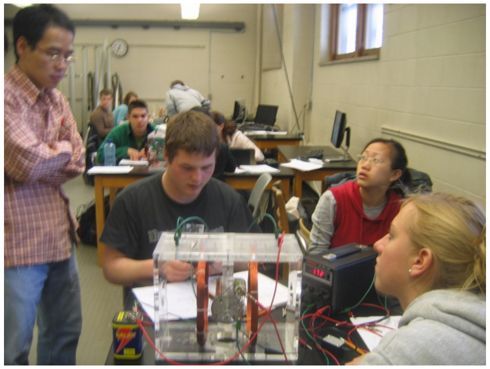
1. What is it?
   1. Goals
   2. Student difficulties
   3. Guidance from learning theory
   4. Course structure
   5. Useful problems
   6. Logical framework
   7. Cooperative groups
2. Does It Work?
   1. Concept assessments
   2. Problem solving assessments

Essential Elements of Cooperative Group Problem Solving

1. Organized Framework for Problem Solving
2. Problems that Require Using an Organized Framework – Context-rich Problems
3. Cooperative Groups to provide support & feedback while solving problems



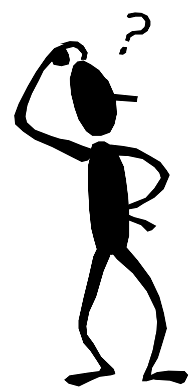
Peer coaching



Instructor coaching

This Afternoon's Workshop – It's All About You

Write down anything you would like to do or talk about in the workshop and give it to us before lunch.



Problem Solving is Necessary

Report on 21st Century Skills, Education & Competitiveness

PARTNERSHIP FOR 21ST CENTURY SKILLS **2008**

- **Thinking critically and making judgments**
- **Solving complex, multidisciplinary, open-ended problems**

The challenges workers face don't come in a multiple-choice format and typically don't have a single right answer. Nor can they be neatly categorized as "math problems"

- **Creativity and entrepreneurial**
- **Communicating and collaborating**
- **Making innovative use of knowledge, information and opportunities**
- **Taking charge of financial, health and civic responsibilities**

University of Minnesota Strategic Planning - 2007

At the time of receiving a bachelor's degree, students will demonstrate the following qualities:

UNIVERSITY OF MINNESOTA

1. **the ability to identify, define, and solve problems**
2. **the ability to locate and evaluate information**
3. **mastery of a body of knowledge and mode of inquiry**
4. **an understanding of diverse philosophies and cultures in a global society**
5. **the ability to communicate effectively**
6. **an understanding of the role of creativity, innovation, discovery, and expression in the arts and humanities and in the natural and social sciences**
7. **skills for effective citizenship and life-long learning.**

What Is Problem Solving?

"Process of Moving Toward a Goal When Path is Uncertain"

- If you know how to do it, its not a problem.

Problems are solved using general purpose tools

Heuristics

Not specific algorithms

"Problem Solving Involves Error and Uncertainty"

A problem for your student is not a problem for you

Exercise vs Problem

M. Martinez, Phi Delta Kappan, April, 1998

Metacognition – Reflecting on Your Own Thought Process

- Managing time and direction
- Determining next step
- Monitoring understanding
- Asking skeptical questions

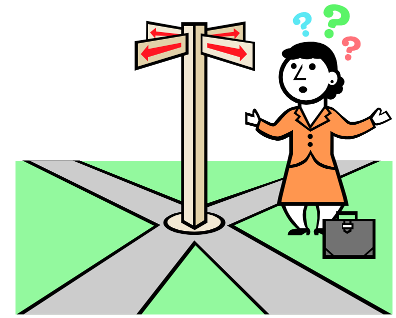
Some General Tools (Heuristics)

- Means - Ends Analysis (identifying goals and subgoals)
- Working Backwards (step by step planning from desired result)
- Successive Approximations (idealization, approximation, evaluation)
- External Representations (pictures, diagrams, graphs, mathematics)
- General Principles of Physics

M. Martinez, Phi Delta Kappan, April, 1998

Solving Problems As Making Decisions Within an Organized Framework

- Visualize situation
- Determine goal
- Choose applicable principles
- Choose relevant information
- Make necessary simplifications
- Construct a plan
- Arrive at an answer
- Evaluate the solution



This is a process not a linear sequence. It requires students to reflect on their work

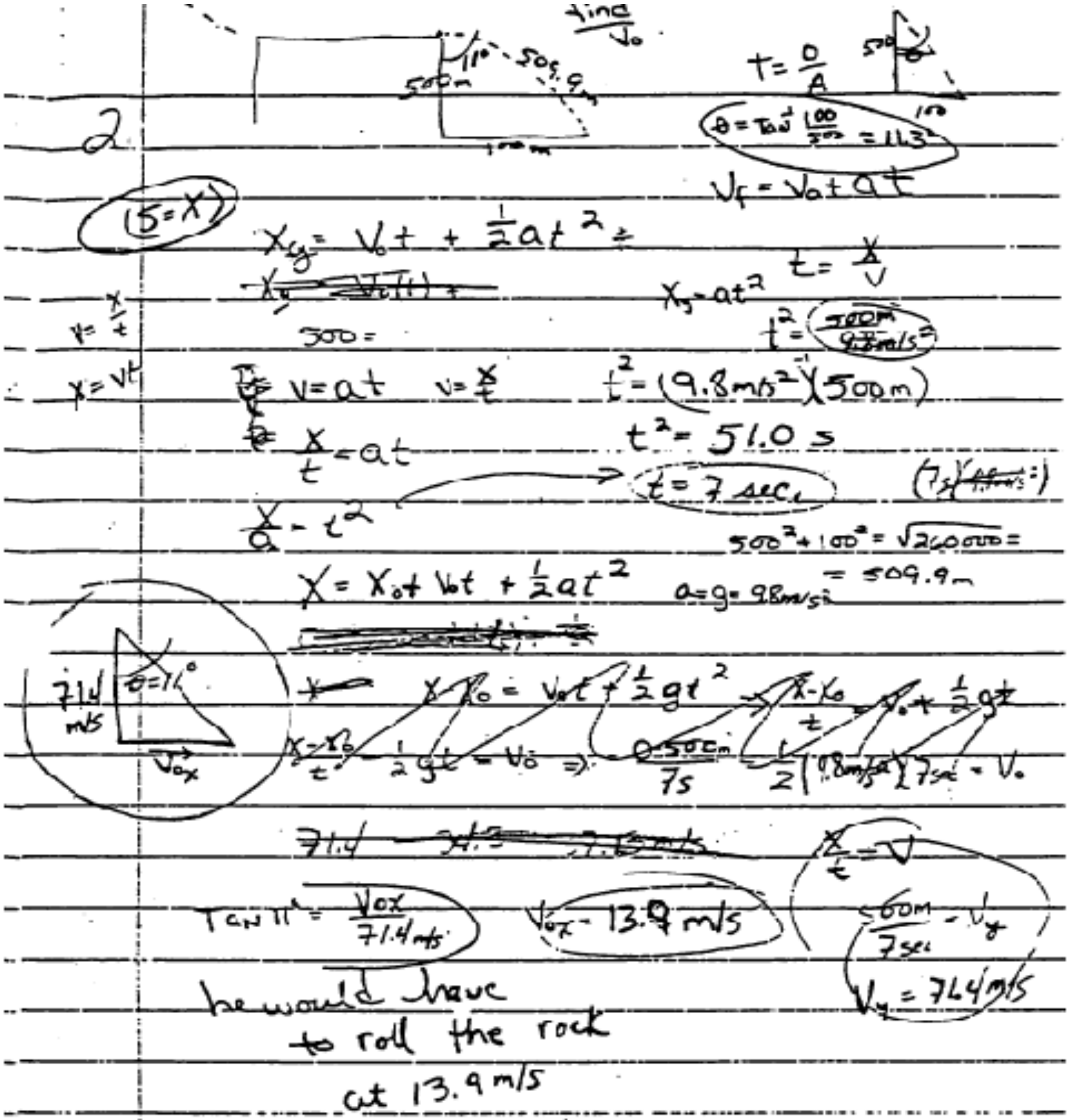
Not natural for most students – must be explicitly taught

To facilitate learning requires problems that

Explicitly connect different concepts

Explicitly connect to reality

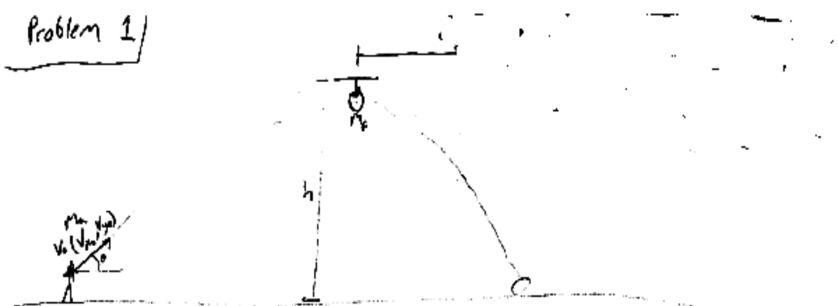
The result of students “natural” problem solving inclinations



Circled work by evaluators

Desired Student Solution

Problem 1



Question: how far away from the tree does the fruit and arrow combination land?

Approach: use conservation of momentum and kinematics

assume constant acceleration due to gravity

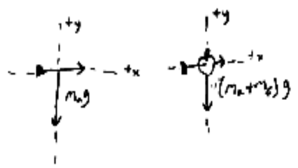
assume no momentum is lost in the collision

neglect wind resistance

use two intervals; from the time the arrow leaves the bow until just before it hits the fruit and just after it hits the fruit until they hit the ground

~~the system is the earth and arrow for the first part, and the fruit and arrow combination and the earth for the second part.~~

Diagram



known: h, m_a, m_f, v_0, θ

unknown: d

Qualitative relationships:

$v_{x0} = v_0 \cos\theta \quad P_f = (m_a + m_f) v_{xf}$

$h = \frac{1}{2} g t^2 \Rightarrow \frac{2h}{g} = t^2, \sqrt{\frac{2h}{g}} = t$

$d = v_{xf} t$

$P_i = P_f \Rightarrow m_a v_{x0} = (m_a + m_f) v_{xf} \Rightarrow v_{xf} = \frac{m_a}{m_a + m_f} v_{x0}$

$P_i = m_a v_{x0}$

Target: d

Plan the Solution: unknown: d

$d = v_{xf} t$ — v_{xf}, t

$v_{xf} = \frac{m_a}{m_a + m_f} v_{x0}$ — v_{x0}

$v_{x0} = v_0 \cos\theta$

$t = \sqrt{\frac{2h}{g}}$

$$d = \frac{m_a}{m_a + m_f} v_0 \cos\theta \sqrt{\frac{2h}{g}}$$

Check units!

$m = \frac{kg}{kg} \frac{m}{s} \sqrt{\frac{m}{m/s^2}}$ ($\to \sqrt{s^2}$)

$m = \left(\frac{m}{s}\right) s$

$m = m \Rightarrow ok$

is the answer complete?

yes, the distance was found in terms of the requested values

is the answer reasonable?

yes, the units check out ok and d will be smaller than h due to conservation of momentum

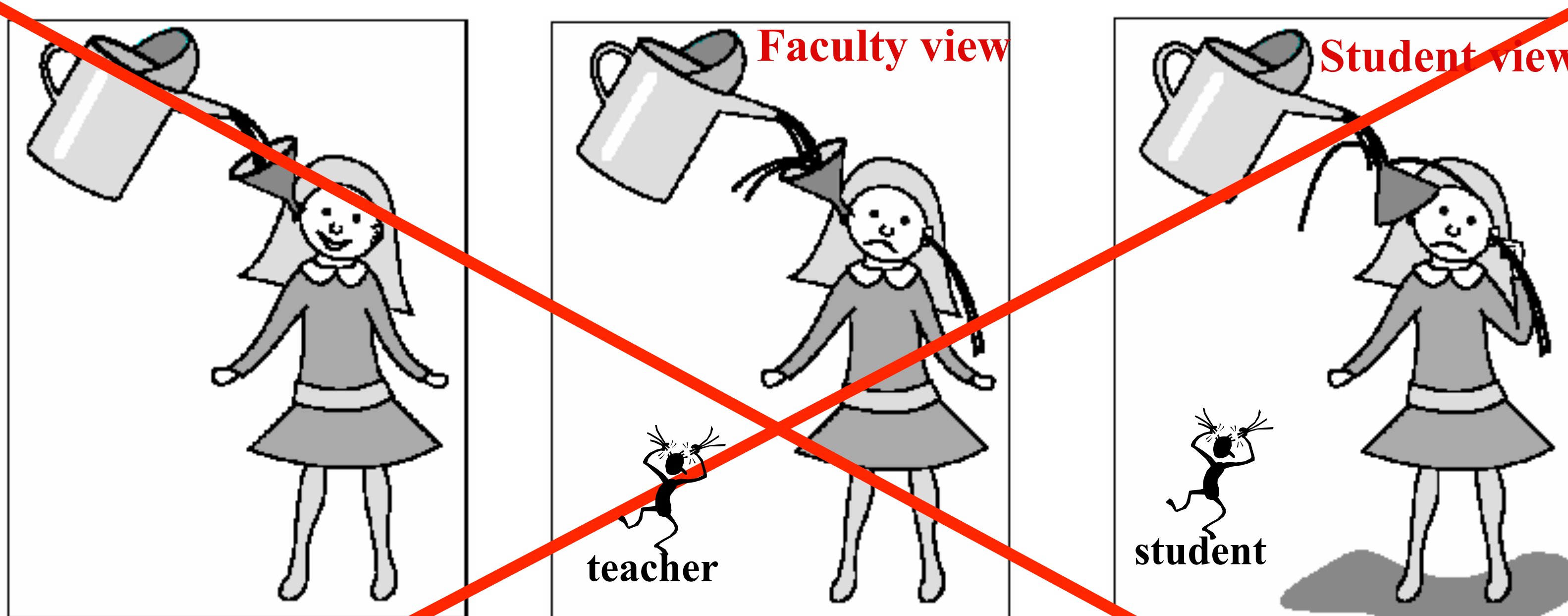
is the answer correctly stated?

yes, it is in units of distance, meters

Impediment to Learning

The Clear Explanation Misconception

Common Source of Frustration of Instructors, Students, & Administrators



Instructor pours knowledge into students by explaining things clearly.

Little knowledge is retained.

Student's Fault

Instructor's delivery is not matched to the student.

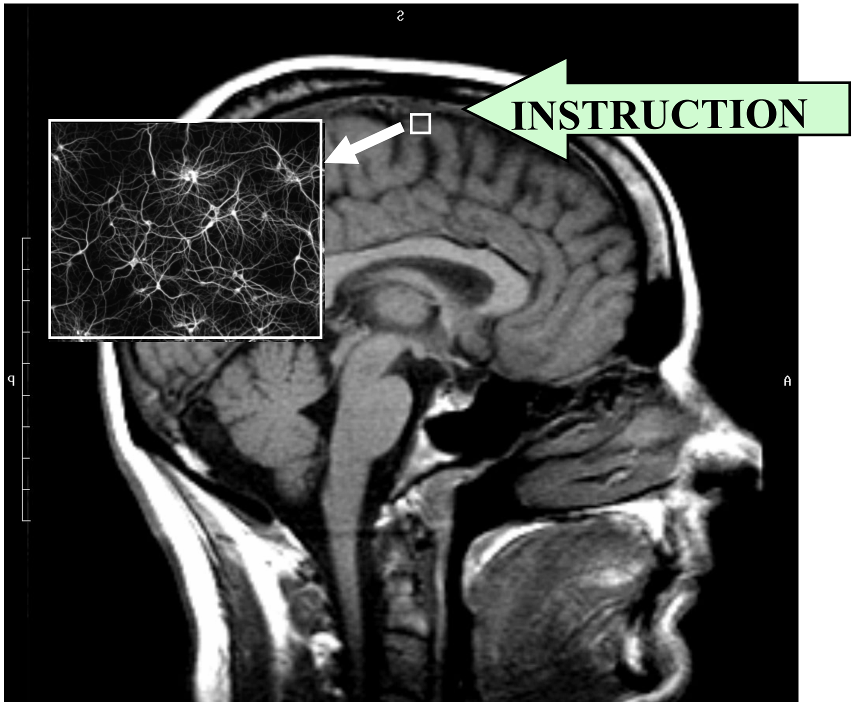
Instructor's Fault

Learning is much more complicated

Leonard et. al. (1999). Concept-Based Problem Solving.

Learning is a Biological Process

Cognitive Science Gives the Constraints



Neurons that fire together, wire together

Simplification of Hebbian theory:
Hebb, D (1949). *The organization of behavior*. New York: Wiley.

Brain MRI from Yale Medical School
Neuron image from Ecole Polytechnique Lausanne

Knowing is an individual's neural interconnections

Something is known if it can be used in novel situations and that usage communicated.

Learning is expanding the neural connection network by changing existing links and establishing new ones

Teaching is the stimulation of each student's neural activity so they renovate their neural connection network.

Teaching requires **Interactive Engagement** (~~Active Learning~~, ~~Activities~~)
Cognitive Apprenticeship

Learning is Difficult

Changing a deeply held way of thinking is traumatic

That trauma is the death of successful ideas and practices.

Death of a loved-one (Elisabeth Kubler-Ross)

- **denial**
- **anger**
- **bargaining**
- **depression**
- **acceptance**

5 stages of reacting to a traumatic event : Learning Expert-like Problem Solving!

DENIAL --- "I don't really have to do all that. I'll try it again my own way! I'll just have to be more careful. I've missed something so I'll read the book or ask someone and then try again."

ANGER --- "%$@^##& professor!", "I shouldn't have to take this course. I should wait until someone else teaches it. It's such a weird way of teaching. This has nothing to do with what I need. These problems are tricky and unclear."

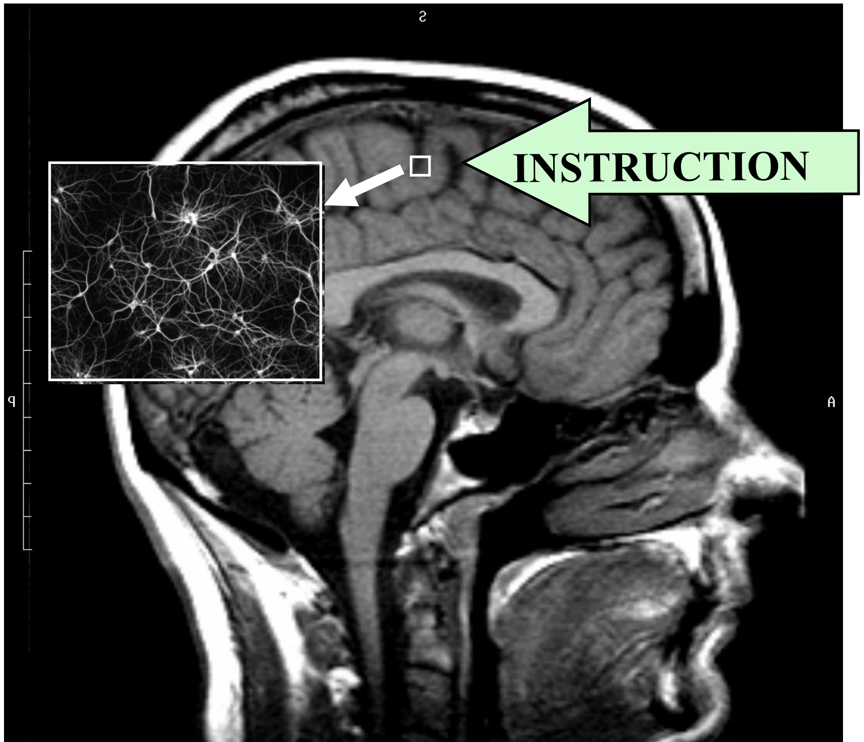
BARGAINING --- "I'll work harder. Can I do extra work for extra credit? Just make the problems clearer and give us enough time to solve them."

DEPRESSION --- "What am I going to do. I'm going to fail. I give up. I'll never be able to pass the course with this rotten professor. What's the use".

ACCEPTANCE --- "Ok. I really need to have a logical and organized process to solve problems. These problems really are the kind of thing I need to be able to solve. I can actually use this technique in my other classes."

Adapted from
Counseling For Loss & Life Changes (1997) http://www.counselingforloss.com/article8.htm

Learning is a Complex Biological Process



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Collins, Brown, & Newman (1990)

Brain MRI from Yale Medical School
Neuron image from Ecole Polytechnique Lausanne

Phenomenological Learning Theory

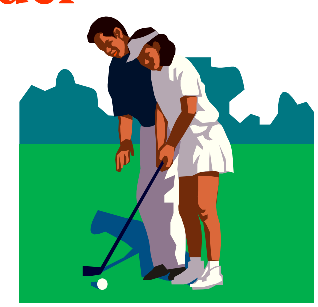
Apprenticeship Works

Cognitive Apprenticeship

Learning in the environment of expert practice

- **Why it is important**
- **How it is used**
- **How is it related to a student's existing knowledge**

model



coach

fade

Fitting into a Traditional Course Structure

LECTURES	**Three hours each week, sometimes with informal cooperative groups, peer coaching. Model constructing knowledge, model problem solving framework.**
DISCUSSION SECTION	**One hour each Thursday -- groups practice using problem-solving framework to solve context-rich problems. Peer coaching, TA coaching.**
LABORATORY	**Two hours each week -- *same* groups practice using framework to solve concrete experimental problems. *Same* TA. Peer coaching, TA coaching.**
TESTS	**Friday -- problem-solving quiz & conceptual questions (usually multiple choice) every three weeks. Fading**

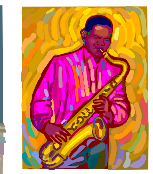
Scaffolding – computer reading tests, clickers, JITT, limit formula usage, sample quizzes, problem solving manual, context rich problems, problem solving labs

Problem-solving Framework

G. Polya, 1945

Used by experts in all fields





Chi, M., Glaser, R., & Rees, E. (1982)

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?

Recorder/checker ________ Skeptic ___________
Manager __________ Summarizer ___________

Focus the Problem

Useful picture and information

Question(s):

Approach:

Describe the Physics

Diagrams and define important quantities:

Target Quantity(ies):

Quantitative Relationships:

Plan the Solution

Construct Specific Equations that Will Lead to an Answer:

Execute the Plan

Scaffolding

Evaluate the Answer

Is the Question Answered in the Correct Units?

Is the Answer Unreasonable?

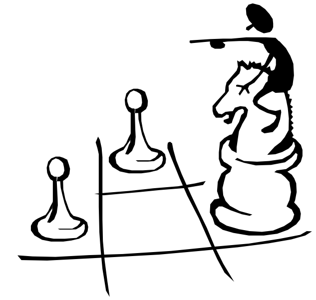
Problem Solving Worksheet used at the beginning of the course

Appropriate Problems for Practicing Problem Solving

The problems must be challenging enough so there is a *real* advantage to using a problem solving framework.

1. **The problem must be complex enough so the best student in the class is not certain how to solve it.**

   The problem must be simple enough so that the solution, once arrived at, can be understood and appreciated by everyone.



2. The problems must be designed so that

• the major problem solving heuristics are required (e.g. physics understood, a situation requiring an external representation);

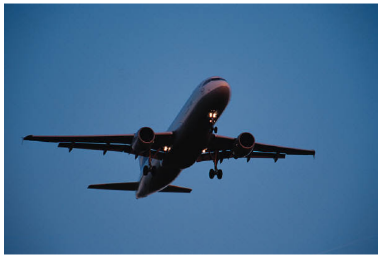
• there are decisions to make in order to do the problem (e.g. several different quantities that could be calculated to answer the question; several ways to approach the problem);

• the problem cannot be resolved in one or two steps by copying a pattern.


3. The task problem must connect to each student's mental processes

   • the situation is real to the student so other information is connected;

   • there is a reasonable goal on which to base decision making.

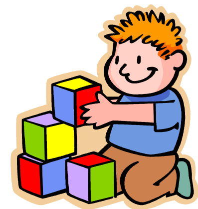
Beginning Context-Rich Problem

You are working with an insurance company to investigate an accident. At the scene, you see a road running straight down a hill at 10° to the horizontal. At the bottom of the hill, the road widens into a small, level parking lot overlooking a cliff. The cliff has a vertical drop of 400 feet to the horizontal ground below where a car is wrecked 30 feet from its base. A witness claims that the car was parked on the hill and began coasting down the road, taking about 3 seconds to get down the hill. Your boss drops a stone from the edge of the cliff and, from the sound of it hitting the ground below, determines that it takes 5.0 seconds to fall to the bottom. You are told to calculate the car's average acceleration coming down the hill based on the statement of the witness and the other facts in the case. Obviously, your boss suspects foul play.

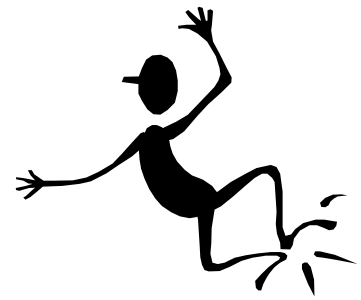
Gives a motivation – allows some students to access their mental connections.
Gives a realistic situation – allows some students to visualize the situation.
Does not give a picture – students must practice visualization.
Uses the character "you" –more easily connects to student's mental framework.

Decisions must be made

The Dilemma



Start with simple problems to learn expert-like framework.



Success using novice framework.

Why change?

Start with complex problems so novice framework fails

Difficulty using new framework.

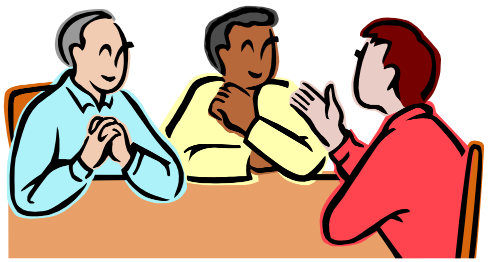
Why change?

Coaching is the necessary ingredient that allows students to work complex problems

Cooperative Groups

Provide peer coaching and facilitate expert coaching

Allow success solving complex problems with an organized framework from the beginning of the course.



- **Positive Interdependence**
- **Face-to-Face Interaction**
- **Individual Accountability**
- **Explicit Collaborative Skills**
- **Group Functioning Assessment**

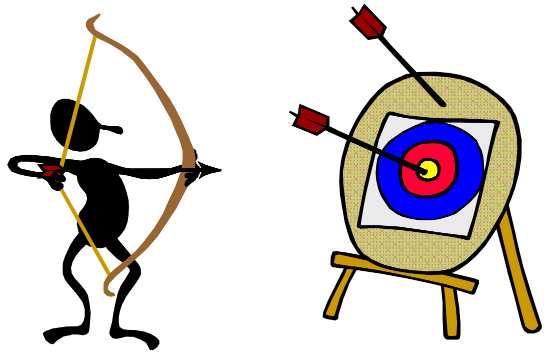
Johnson & Johnson, 1978

Email 8/24/05

Another good reason for cooperative group methods: this is how we solve all kinds of problems in the real world - the real academic world and the real business world. I wish they'd had this when I was in school. Keep up the great work.

Rick Roesler Vice President, Handhelds Hewlett Packard

Some Goals of Cooperative Group Problem Solving



- Students can make both qualitative and quantitative predictions about the real world from a few basic physics principles.

- Students will know the difference between fundamental principles and specific applications.

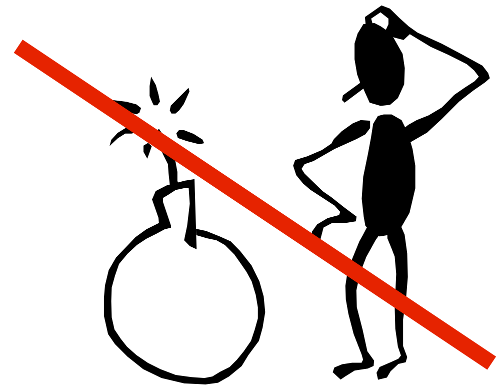
- Students can make decisions, know the assumptions that underlie them, and be able to evaluate them.

- Students can construct and communicate a long chain of logic (including mathematics) to themselves and others.

Identify Critical Failure Points

Fail Gracefully

Non-optimal implementation gives reasonable success



1. Inappropriate Tasks

Engage all group members (not just one who knows how to do it)

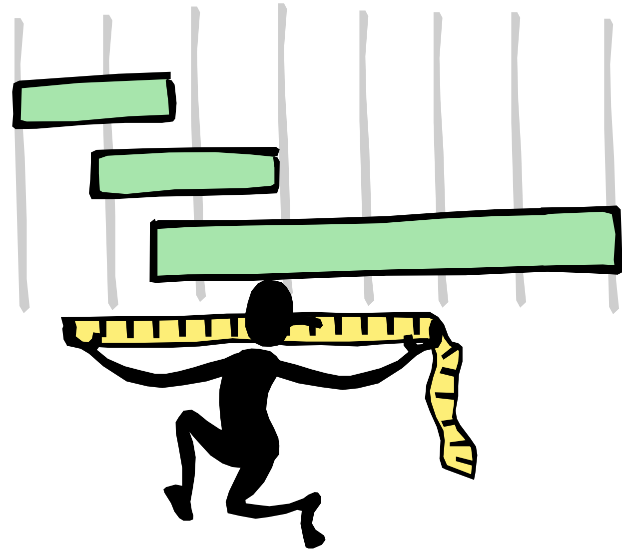
2. Inappropriate Grading

Don’t penalize those who help others (no grading on the curve)

Reward for individual learning (not just a group product)

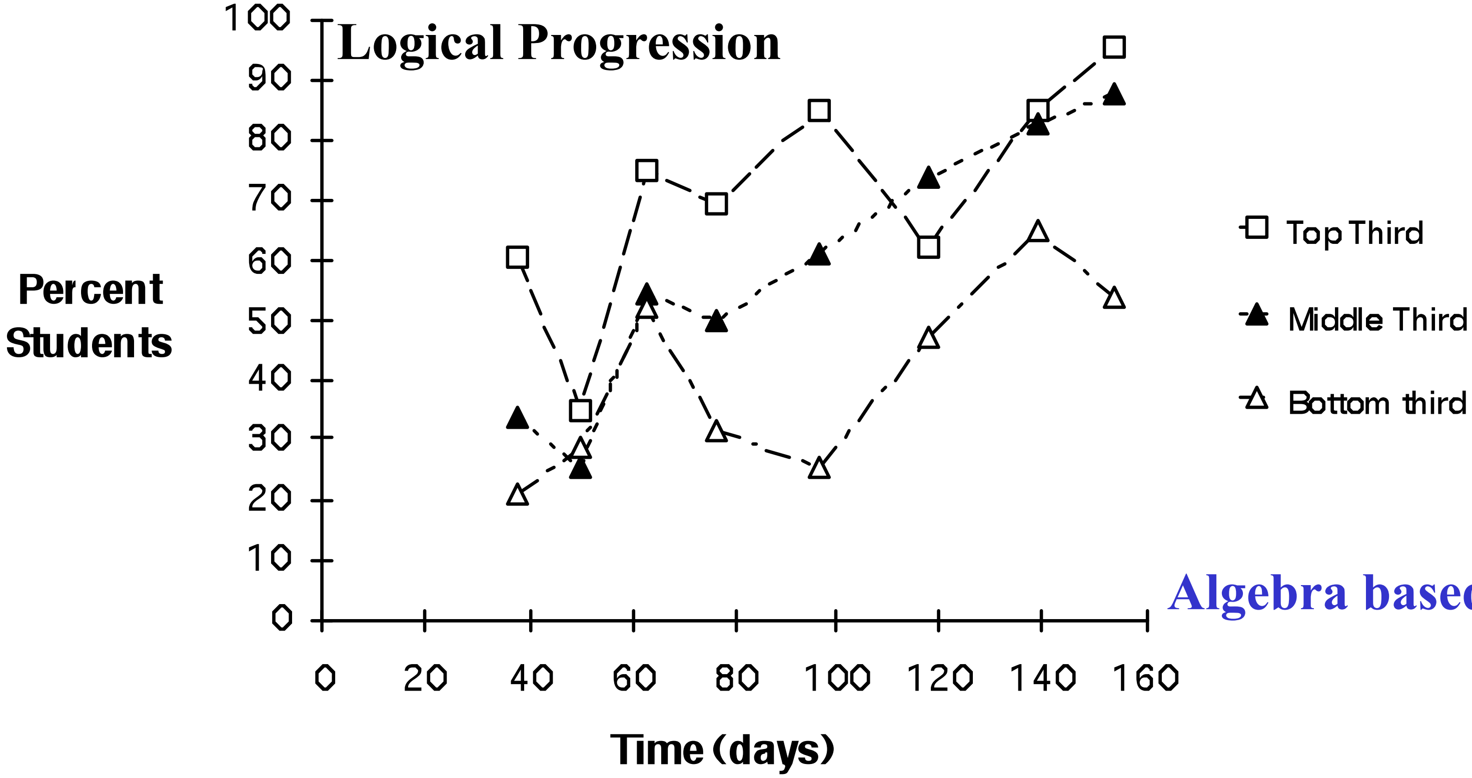
3. Poor structure and management of Groups

Assessment



- Problem Solving Skill
- Drop out rate
- Failure rate
- FCI – some mechanics concepts
- BEMA – some E&M concepts
- CLASS – attitudes toward learning physics
- Math Skills
- What students value in the course
- Engineering student longitudinal study
- Faculty use
- Adoption by other institutions and other disciplines

Improvement in Problem Solving



Algebra based physics 1991

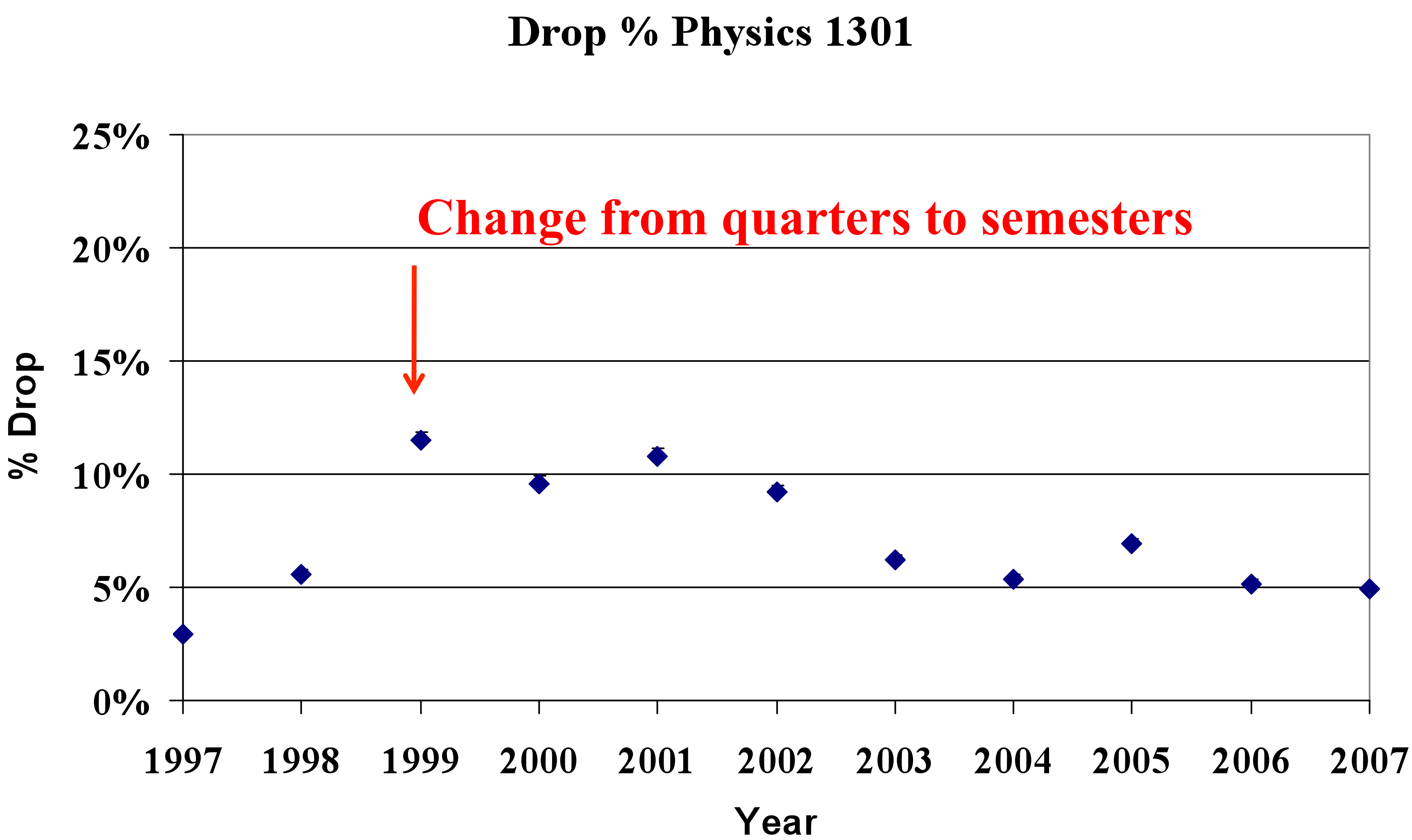
General Approach - does the student understand the physics

Specific Application of the Physics - starting from the physics they used, how did the student apply this knowledge?

Logical Progression - is the solution logically presented?

Appropriate Mathematics - is the math correct and useful?

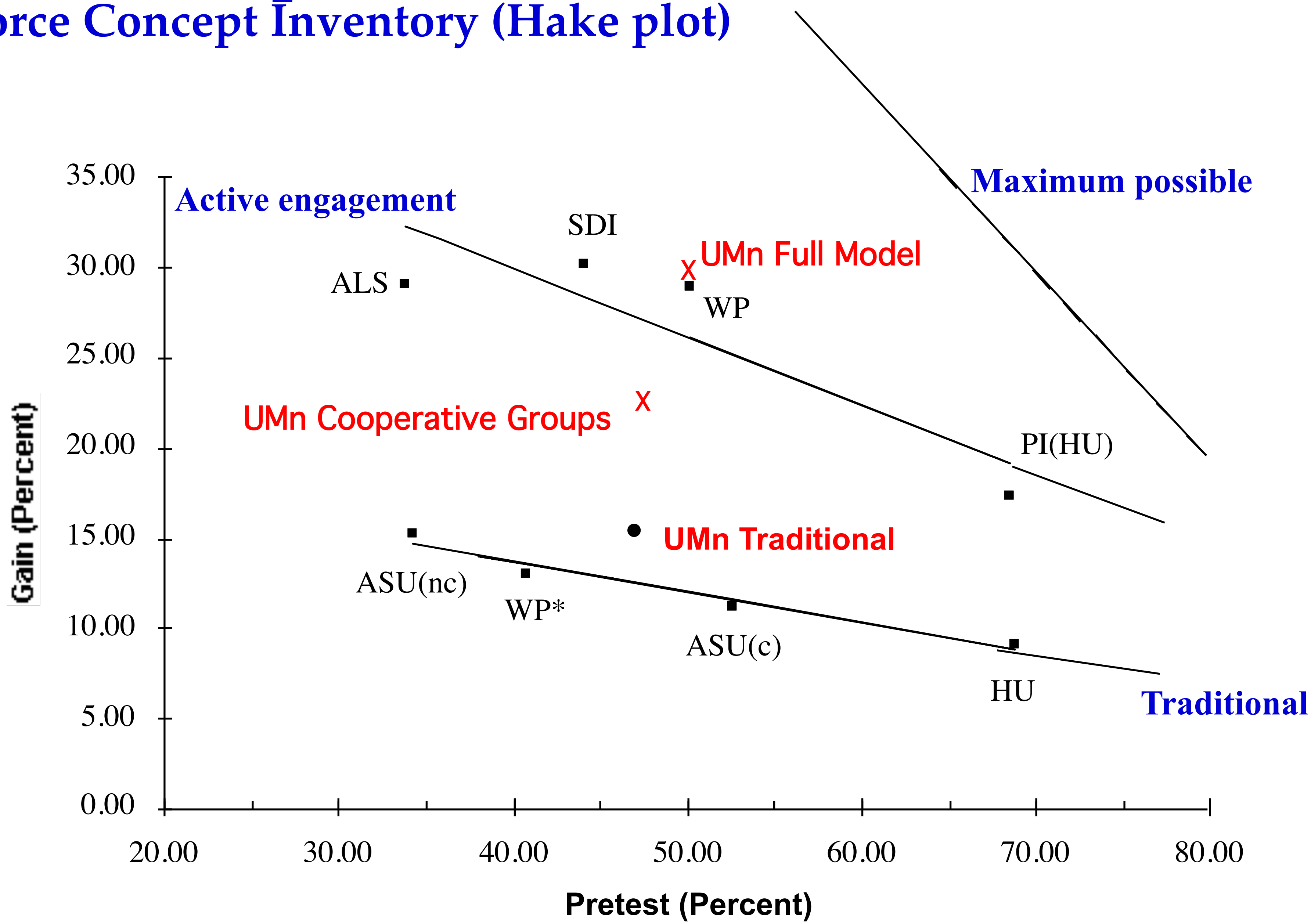
Retention

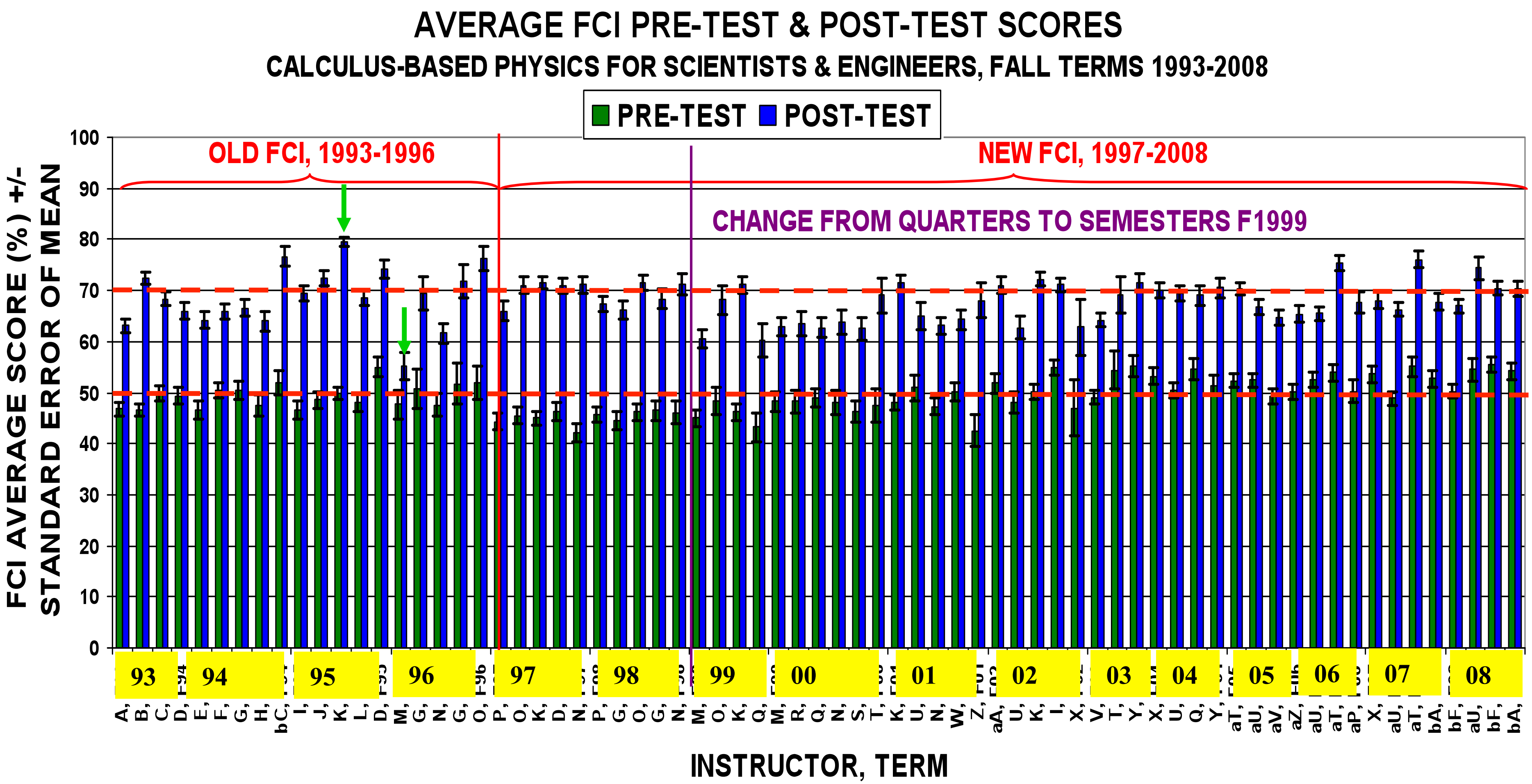


Dropout rate ~ 6%, F/D rate ~ 3% in all classes

Conceptual Gain

Force Concept Inventory (Hake plot)





Each letter represents a different professor (39 different ones)

- **Incoming student scores are slowly rising (better high school preparation)**
- **Our standard course (CGPS) achieves average FCI ~70%**
- **Our "best practices" course achieves average FCI ~80%**
- **Not executing any cooperative group procedures achieves average FCI ~50%**

The End

Please visit our website for more information:

http://groups.physics.umn.edu/physed/

The best is the enemy of the good.

"le mieux est l'ennemi du bien"

Voltaire