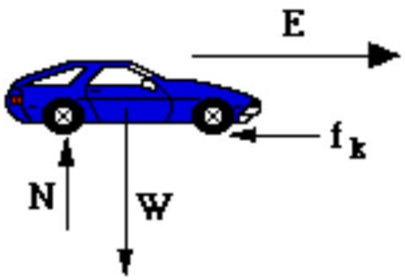
# Helping Your Students Develop Expertise in Problem Solving – While Learning Physics




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


**Ken Heller**

**School of Physics and Astronomy**
**University of Minnesota**


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

**For a detailed guide to Cooperative Group Problem Solving**
**google: AAPT new faculty workshop**
**For other information google: PER minnesota**

UNIVERSITY OF MINNESOTA

# UofM Introductory Physics – focus on problem solving

**LECTURES**

Three hours each week, sometimes with informal cooperative groups, peer coaching. Demonstrate constructing knowledge & using the problem solving framework. (250 students)

**DISCUSSION SECTION**

One hour each Thursday -- groups practice using problem-solving framework to solve context-rich problems. Peer coaching, TA coaching. (18 students)

**LABORATORY**

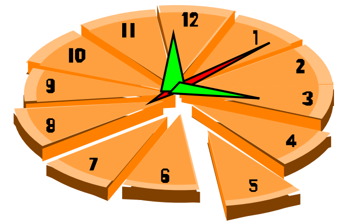
Two hours each week -- *same* groups practice using framework to solve concrete experimental problems. *Same* TA. Peer coaching, TA coaching. (18 students)

**TESTS**

Friday -- problem-solving quiz & conceptual questions (usually multiple choice) every three weeks.

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

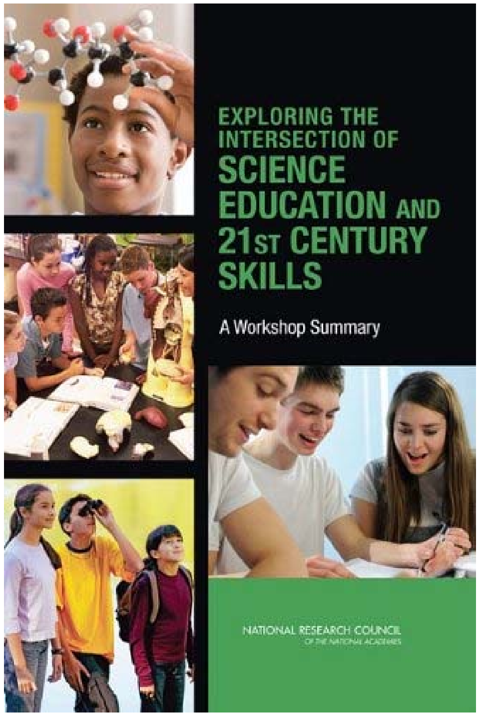
# Improving Student Problem Solving
# A Guide for Discussion




- Why Teach Problem Solving?
- What Is Meant by Problem Solving?
  - Real problem solving requires conceptual understanding.
- Context from learning theory –
  - The basis of all the NFW pedagogy.
- Measuring Problem Solving
- Strategies for Teaching Problem Solving
  1. Experts & Novices – Organizational Framework
  2. Useful & Not Useful Problems
  3. Implementation & Scaffolding
     - Coaching and Groups
     - Role for Computers
- Critical Failure Modes
- Some Results
  - Teaching Problem Solving Increases Conceptual Understanding

Decide on what details you want to discuss in the break-out session tomorrow.

# Problem Solving is Necessary




NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES (2010)

## 21st Century Skills

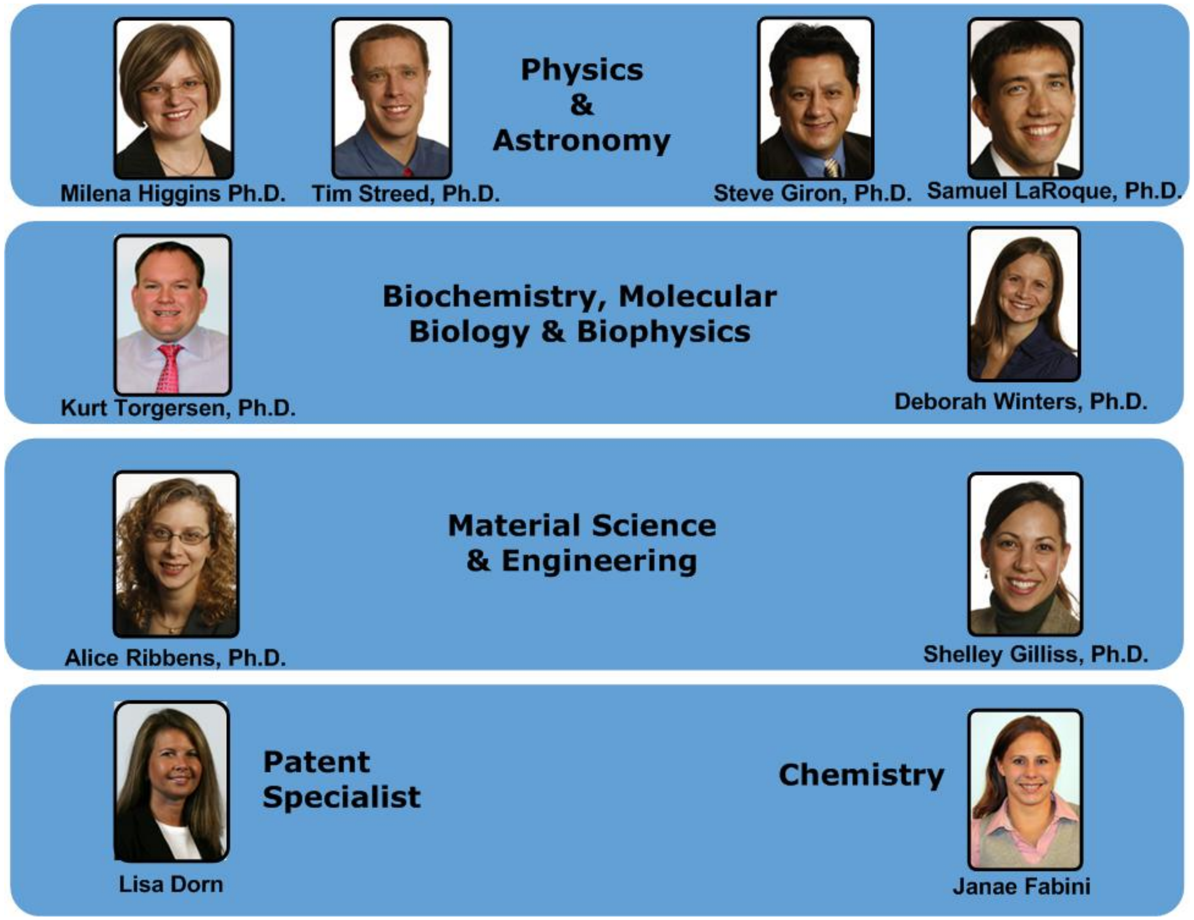
- Adaptability:
- Complex communication/social skills:
- Self-management/self-development:
- Systems thinking:
- Nonroutine problem solving:

- Diagnose the problem.
- Link information.
- Reflect on solution strategy.
- Switch strategy if necessary.
- Generate new solutions.
- Integrate seemingly unrelated information.

The use of physics outside of Physics

# Science Advisors

ROBINS, KAPLAN, MILLER & CIRESI L.L.P.




Physics Department Open House 11/11/10

What's a Physicist Doing in a Law Firm?

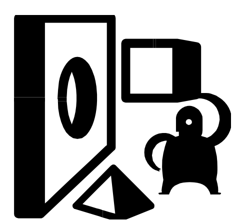
Milena Higgins

Chief Scientist

U of Mn PhD 1996 Biophysics

Q: How has Physics Helped You?

A: "It's all problem solving!"



# University of Minnesota Strategic Planning - 2007

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

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 Do Other Faculty Want? (5 pt scale)

**Goals: Calculus-based Course (88% engineering majors) 1993**

- 4.5 Basic principles behind all physics
- 4.5 General qualitative problem solving skills
- 4.4 General quantitative problem solving skills
- 4.2 Apply physics topics covered to new situations
- 4.2 Use with confidence

**Goals: Algebra-based Course (24 different majors) 1987**

(5 pt scale)

- 4.7 Basic principles behind all physics
- 4.2 General qualitative problem solving skills
- 4.2 Overcome misconceptions about physical world
- 4.0 General quantitative problem solving skills
- 4.0 Apply physics topics covered to new situations

**Goals: Biology Majors Course 2003**

- 4.9 Basic principles behind all physics
- 4.4 General qualitative problem solving skills
- 4.3 Use biological examples of physical principles
- 4.2 Overcome misconceptions about physical world
- 4.1 General quantitative problem solving skills

# The Nature of Science is Problem Solving

"All science is either physics (quantitative problem solving) or stamp collecting (cataloging information)."

Awarded the 1908 Nobel Prize in Chemistry

"I must confess I am very startled at my metamorphosis into a chemist."

Ernest Rutherford

**Concepts and problem solving are intimately connected in science.**

Concepts are invented to solve problems.

- How do the Sun, Moon, Stars, Planets move around the Earth?
- How does an arrow fly through the air?
- How can an atom be stable?
- How can our Universe exist?

Those concepts are connected by a theoretical framework that is fruitful if it can be used to solve other problems.

Problem solving is a complex and creative process of decisions connecting what you know to what you don't.

To be science, problem solving is constrained by certain rules

- Logic
- Mathematics
- Testability
- Consistency
- Universality

## TASK – assume you are teaching introductory physics

**Decide whether or not you think the following two questions are problems.**

**Decide if they useful in teaching physics?**

**Report your reasoning.**

## TIME ALLOTTED

**5 minutes/problem**

## PROCEDURES

**Form a group of 3 or 4 people**

**If you don't know everyone, introduce yourself**

**Choose one person as a reporter**

***Formulate*** **a response individually.**

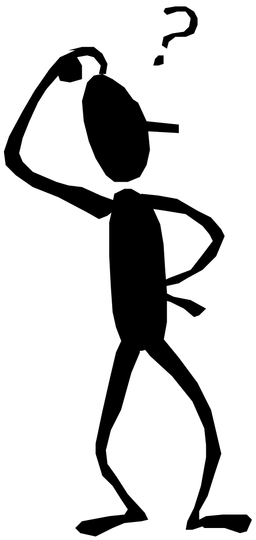
***Discuss*** **your response with your partners.**

***Listen*** **to your partners' responses.**

***Create*** **a group response through discussion.**

# Is this a Problem?

**A block starts from rest and accelerates for 3.0 seconds. It then goes 30 ft. in 5.0 seconds at a constant velocity.**




a. What was the final velocity of the block?

b. What was the acceleration of the block?

**Why or why not?**

**Is it useful for teaching physics?**

From a physics textbook

# Is this Is a Problem?

You have a summer job with the police CSI unit and are helping to investigate a tragic incident.  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 ground below where a car is wrecked 30 feet from the base of the cliff.  A witness claims 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 determines that it takes 5.0 seconds to hit 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.

Why or why not?

Is it useful for teaching physics?

# According to Cognitive Science

**A problem is a situation that you do not know how to resolve.**

**If you know how to do it,
it is not a problem.**

**Solving a problem requires making decisions about connecting what you know in new ways.**

**M. Martinez, Phi Delta Kappan, April, 1998**

# Solving Physics Problems

## An organized way of making decisions that requires:

- Visualizing a situation
- Specifying goals
- Making assumptions
- Identifying useful ideas
- Learning new ideas
- Connecting ideas using techniques such as diagrams, logic, mathematics
- Evaluating the process and its results

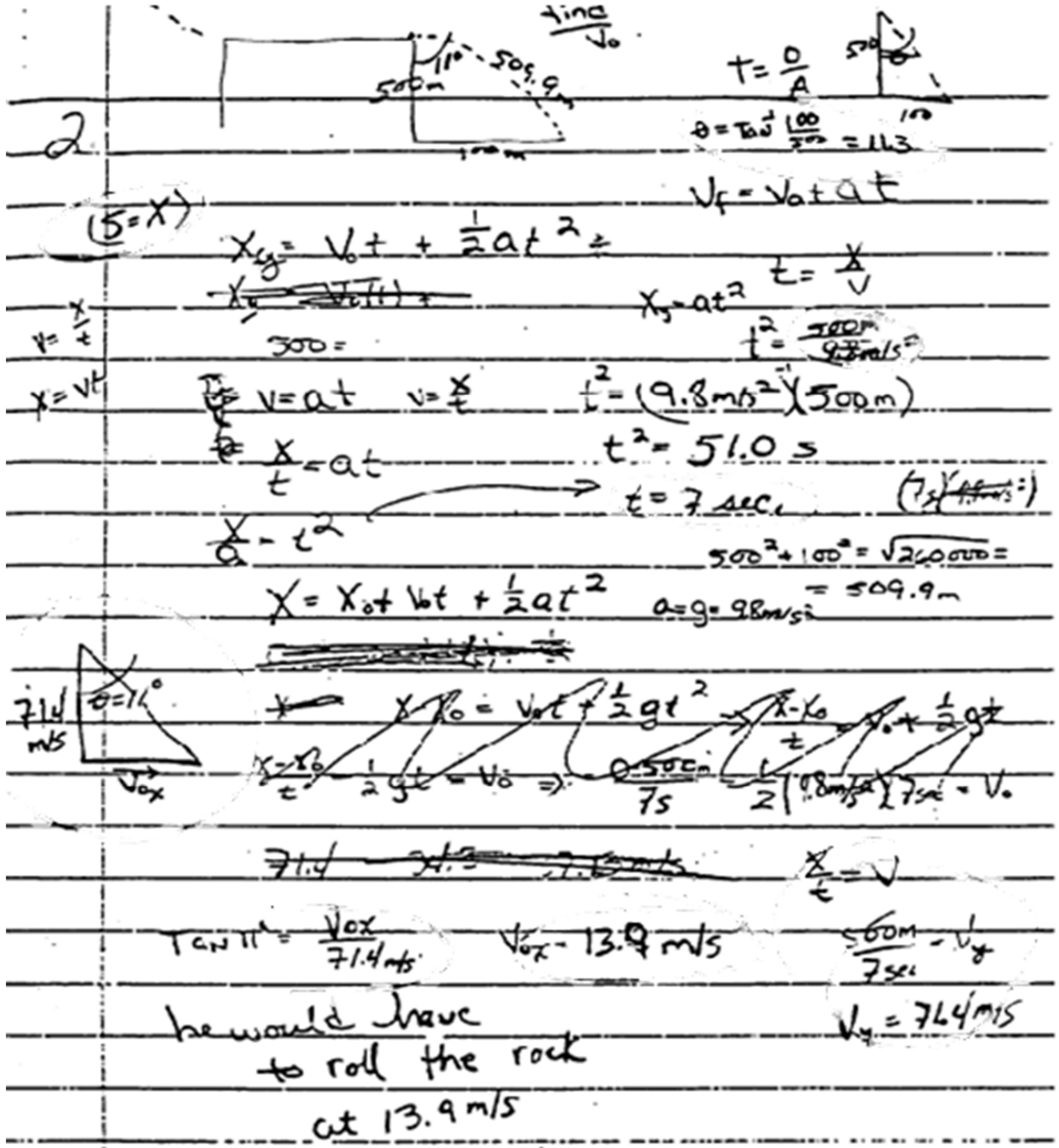
Expert: Solving a problem requires constructing a set of decisions that logically connect the situation to the goal using a few basic principles.

Novice: Solving a problem requires a following a recipe that connects the situation to the goal. Every situation has its own recipe.

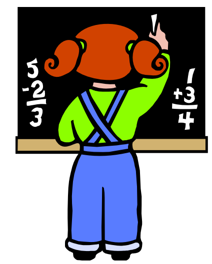
# The result of students “natural” problem solving inclinations

**Trying to solve a problem by following a recipe gives disconnected recipe fragments.**

**Does not look like following a recipe**



# Novice Problem-solving Framework



**STEP 1**

What Kind of Problem is This?

Which pattern does it match?

**STEP 2**

What Equations Are Needed?

One should match this situation

**STEP 3**

Do Some Math

Plug in numbers

**STEP 4**

Do Some More Math

Manipulate equations to get an answer.

**STEP 5**

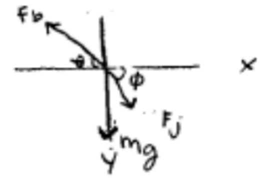
Is It Done?

Did I get an answer?

# Problem Solving After Instruction

Knowns
$\theta = 80°$
$V_m = 3.76\ L = 3760\ mL$


Force Diagram




Target: $F_j$ = Force of joint

Approach: Use Forces
$\Sigma F_x = 0$
$\Sigma F_y = 0$
Use Torque
$\Sigma \tau = 0$

$\rho = \frac{m}{V}$

$\rho V_m = m$

**Trying to solve a problem by making logically connected decisions looks like following a recipe.**

assume density of milk is similar to water. $= 1\ g/cm^3 = 1\ g/mL = .001\ kg/mL$

$\Sigma F_x = 0$
$F_{jx} - F_{bx} = 0$

$\Sigma F_y = 0$

$F_{by} - mg - F_{jy} = 0$

$\Sigma \tau = 0$ (joint is pivot point)

$F_{by}(1/6\,L) - mgL = 0$

$F_b \cos\theta = F_{bx}$
$F_b \sin\theta = F_{by}$
$F_{jy} = F_j \sin\phi$
$F_{jx} = F_j \cos\phi$

$F_j^2 = F_{jx}^2 + F_{jy}^2$

43.3 N is the amount needed to lift an ≈ 4.3 kg object straight off the ground. this is reasonable

Plug in $\phi$ — $\rho V$ for $m$

$$F_j = \sqrt{\left(\frac{6\rho V g}{\sin\theta}\cos\theta\right)^2 + (5\rho V g)^2}$$

$$= \sqrt{\left(\frac{6(.001)3760\,g}{\sin 80}\cos 80\right)^2 + (5(.001)(3760\,g))^2} =$$

$$\boxed{43.3\ N}$$

units $\left(\frac{kg}{mL}\cdot mL\,\frac{m}{s^2}\right)^2 + \left(\frac{kg}{mL}\cdot m\cdot\frac{m}{s^2}\right)^2 = \sqrt{\frac{kg^2 m^2}{s^4}} = kg\,m/s^2 = N$ ✓

| equation | | unknown |
|---|---|---|
| $F_j^2 = F_{jx}^2 + F_{jy}^2$ | 1 | $F_{jx}$, $F_{jy}$ [1] [2] |
| $F_{by} - mg - F_{jy} = 0$ | 2 | $F_{by}$ [3] |
| $F_{jx} - F_{bx} = 0$ | 3 | $F_{bx}$ [4] |
| $F_{by}(1/6\,L) - mgL = 0$ | 4 | |
| $F_{bx} = F_b \cos\theta$ | 5 | $F_b$ [5] |
| $F_{by} = F_b \sin\theta$ | 6 | $F_j$ [6] |

$F_b = \frac{F_{by}}{\sin\theta}$

$\frac{F_{by}}{\sin\theta}\cos\theta = F_{bx}$

$6mg = F_{by}$

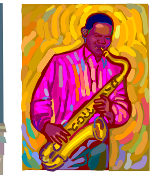
$F_{jx} = \frac{6mg}{\sin\theta}\cos\theta$

$F_{jy} = F_{by} - mg = 6mg - mg$

$$F_j = \sqrt{\left(\frac{6mg}{\sin\theta}\cos\theta\right)^2 + (6mg - mg)^2}$$

# Problem-solving Framework
## Used by experts in all fields





G. Polya, 1945

**STEP 1** Recognize the Problem

What's going on and what do I want?

Not a linear sequence. Requires continuous reflection and iteration.

**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 what I want?

**STEP 4** Execute the plan

Let's get the answer.

**STEP 5** Evaluate the solution

Can this be true?

"I was a student in first year physics you taught 20 years ago. Since those days I have made a good living as an RF integrated circuit design engineer. I am writing to let you know not a week goes by without a slew of technical problems to be solved, and the first thing that comes to mind is the "define the problem" which I recently reminded myself that it was you who instilled this ever so important step in problem solving. I would like to thank you because your influence has helped me excel and become a better engineer."

email received June, 2012

# A Physics Problem-solving Framework

**STEP 1** Focus the Problem

Draw a picture of the situation
Define useful quantities: identify what you know & don't know
State the question in terms of something you can calculate.

**STEP 2** Describe the physics

State general principles that might be useful to approach this problem
Give any constraints imposed by the situation
State any approximations that might be useful
Draw any diagrams that might be useful
Translate the general principles into equations specific to the situation

**STEP 3** Plan a solution

Identify your target quantity
Construct a chain of equations linking your target to known quantities
Check to see if you have sufficient equations

**STEP 4** Execute the plan

Follow your plan to calculate an answer
Check your units

The only math

**STEP 5** Evaluate the solution

Did you answer the question?
Justify that your answer is not unreasonable?

Instructor demonstrates this framework for all examples solved in class

Scaffolding

# Grading Guidance on Each Test

This is a closed book, closed notes quiz. Calculators are permitted. The ONLY formulas that may be used are those given below. Define all symbols and justify all mathematical expressions used. Make sure to state all of the assumptions used to solve a problem. Credit will be given only for a logical and complete solution that is clearly communicated with correct units. Partial credit will be given for a well communicated problem solving strategy based on correct physics. MAKE SURE YOUR NAME, ID #, SECTION #, and TAs NAME ARE ON EACH PAGE!! START EACH PROBLEM ON A NEW PAGE. Each problem is worth 25 points: In the context of a unified solution, partial credit will be awarded as follows:

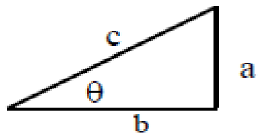
- a useful picture, defining the question, and giving your approach is worth 6 points;
- a complete physics diagram defining the relevant quantities, identifying the target quantity, and specifying the relevant equations with reasons is worth 6 points;
- planning the solution by constructing the mathematics leading to an algebraic answer and checking the units of that answer is worth 7 points;
- calculating a numerical value with correct units is worth 3 points; and
- evaluating the validity of the answer is worth 3 points.

# Control Equations: Only these are allowed

**Equation sheet on the final exam for 1st semester: Calculus Based Physics for Biology Majors**

**45 equations**

**Useful Mathematical Relationships:**




For a right triangle: $\sin\theta = \frac{a}{c}$, $\cos\theta = \frac{b}{c}$, $\tan\theta = \frac{a}{b}$,

$a^2 + b^2 = c^2$, $\sin^2\theta + \cos^2\theta = 1$

For a circle: $C = 2\pi R$, $A = \pi R^2$

If $Ax^2 + Bx + C = 0$, then $x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

$\frac{d(z^n)}{dz} = nz^{n-1}$, $\frac{d(\cos z)}{dz} = -\sin z$, $\frac{d(\sin z)}{dz} = \cos z$, $\frac{d(e^{az})}{dz} = ae^{az}$, $\frac{d(\ln z)}{dz} = \frac{1}{z}$, $\frac{df(z)}{dt} = \frac{df(z)}{dz}\frac{dz}{dt}$,

$\int \left(\frac{df}{dz}\right) dz = f$

**Fundamental Concepts, Principles, and Definitions:**

| | | | | | | |
|---|---|---|---|---|---|---|
| $\sum \vec{F} = m\vec{a}$ | $\rho = \frac{m}{V}$ | $\tau = rF_\perp$ | $\vec{\tau} = \vec{r} \times \vec{F}$ | $KE = \frac{1}{2}mv^2$ | $v_{x\,av} = \frac{\Delta x}{\Delta t}$ | $\frac{dx}{dt} = v_x$ |
| $s_{av} = \frac{\text{distance}}{\Delta t}$ | $a_{x\,av} = \frac{\Delta v_x}{\Delta t}$ | $\frac{dv_x}{dt} = a_x$ | $E_f - E_i = E_{in} - E_{out}$ | $\frac{dE_{transfer}}{d\ell} = F_\ell$ | | |
| $e = \frac{E_{desired}}{E_{input}}$ | $\sigma = \frac{F}{A}$ | $\varepsilon = \frac{\Delta L}{L}$ | $E = \frac{\sigma}{\varepsilon}$ | $P = \frac{F}{A}$ | $\mathcal{P} = \frac{dE}{dt}$ | |
| $\frac{d\mathcal{U}}{d\ell} = -F_{internal\,\ell}$ | $\theta = \frac{\delta C}{r}$ | $\mathcal{F} = \mathcal{U} - TS$ | $S = k\ln\Omega$ | $f = \frac{1}{T}$ | | |

**Under Certain Conditions:**

| | | | | | | |
|---|---|---|---|---|---|---|
| $\sum F_x = 0$ | $F = mg$ | $F = kx$ | $F = \mu_k n$ | $F \le \mu_s n$ | $\sum \tau = 0$ | $\Delta E = mL$ |
| $\frac{dW}{dV} = P$ | $\mathcal{U} = mgh$ | $\mathcal{U} = \frac{1}{2}kx^2$ | $\frac{dQ}{dt} = e\sigma AT^4$ | $\frac{dQ}{dt} = \kappa\frac{A}{L}\Delta T$ | | |
| $\Delta E = cm\Delta T$ | $\Delta E = cn\Delta T$ | $PV = NRT$ | $PV = nkT$ | $Q = Av$ | $W = -T\Delta S$ | |
| $\mathcal{P} = Q\,\Delta P$ | $\Delta P = QR$ | $F = bv$ | $a = \frac{v^2}{r}$ | | | |

**Useful Constants:** 1 mile = 5280 ft, $g = 9.8\ m/s^2 = 32\ ft/s^2$, $k_B = 1.4 \times 10^{-23}$ J/K, $N_{av} = 6 \times 10^{23}$, $R = 8.3$ J/(mol K), $\rho_{water} = 1\ g/cm^3$, $P_{atm} = 10^5$ Pa

# Measureing Expert-like Problem Solving

## Almost Independent Dimensions

- **Useful Description**
  - organize information from the problem statement symbolically, visually, and/or in writing.
- **Physics Approach**
  - select appropriate physics concepts and principles
- **Specific Application of Physics**
  - apply physics approach to the specific conditions in problem
- **Mathematical Procedures**
  - follow appropriate & correct math rules/procedures
- **Logical Progression**
  - overall the solution progresses logically; it is coherent, focused toward a goal, and consistent (not necessarily linear)

J. Docktor (2009) based on previous work by:

J. Blue (1997); T. Foster (2000); T. Thaden-Koch (2005);

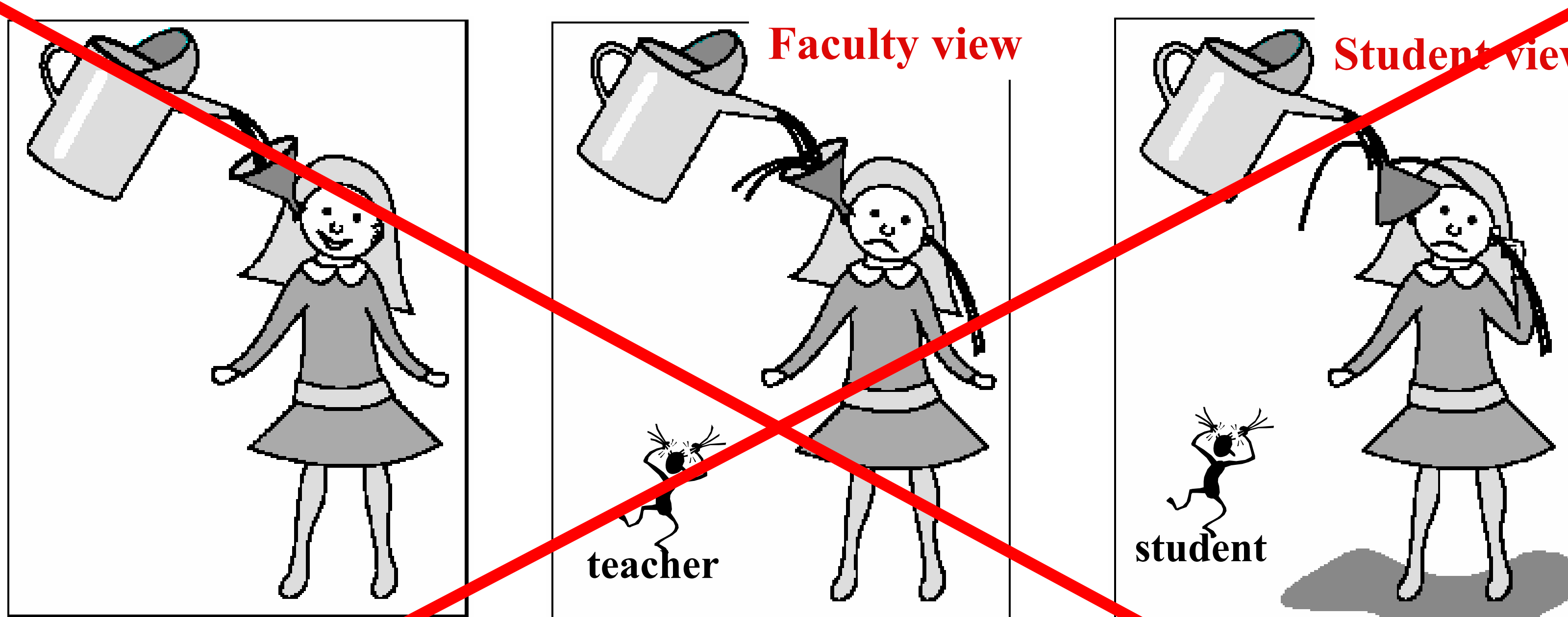
P. Heller, R. Keith, S. Anderson (1992)

# Teaching Physics Through Problem Solving

## Explaining $\neq$ Teaching

## The Clear Explanation Misconception of Teaching

**Common Source of Frustration of Faculty, TAs, Students, & Administrators**




**Instructor pours knowledge into students by explaining things clearly.**

**Little knowledge is retained.**

**Student's Fault**

**Impedance mismatch between student and instructor.**

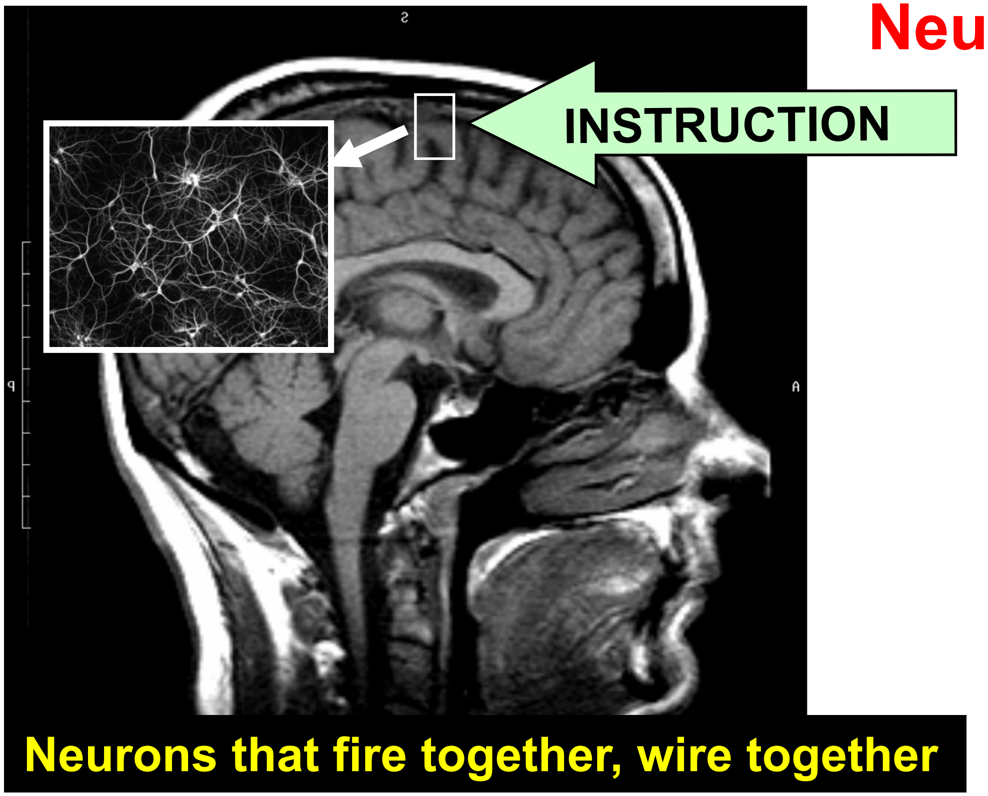
**Instructor's Fault**

**Learning is much more complicated**

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

# Learning is a Biological Process

## Neural Science Gives Constraints




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

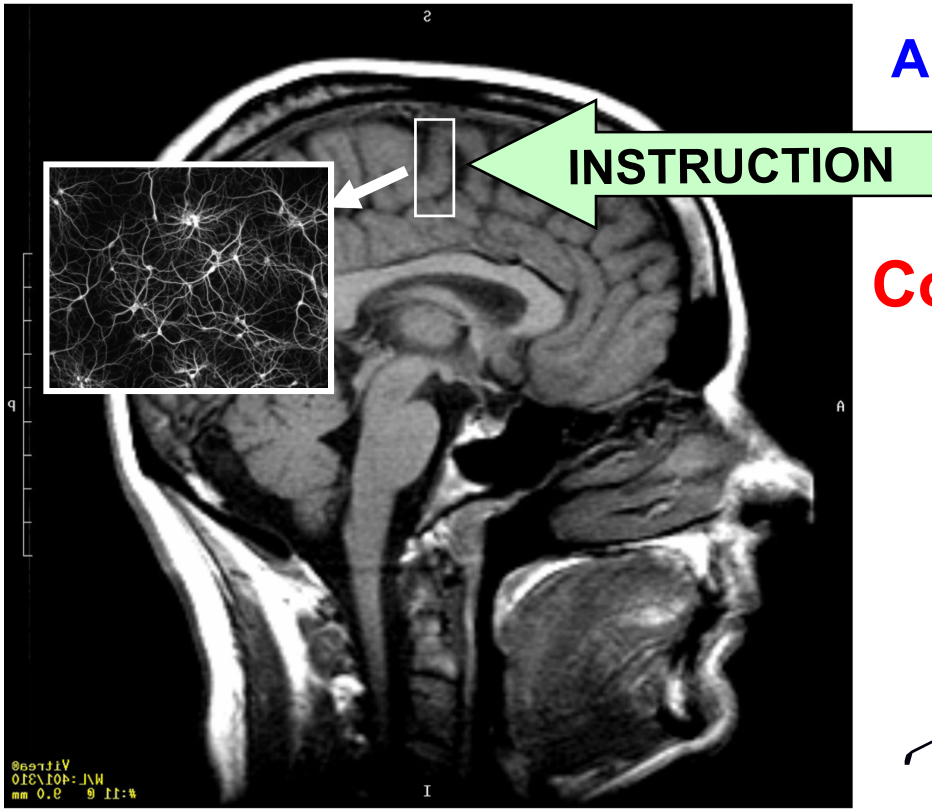
Operationally, a student knows something if they can use it in novel (for them) situations and communicate that usage.

**Learning** is expanding and changing the network of neural connections

**Teaching** is putting the student in a situation that stimulates their neural activity to renovate the relevant network of neural connections.

Teaching requires **Mental Engagement**

# Learning is Too Complex to Predetermine




Apprenticeship Works

## Cognitive Apprenticeship

Learning in the environment of expert practice

- Why it is important?
- How it is used?
- How is it related to what I already know?

model

coach

fade

Collins, Brown, & Newman (1990)

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

# Learning in the environment of expert practice

Solving problems is hard especially if you don't have a framework

Support is necessary

If you don't know about the box, you can't think outside the box.

You can't learn to solve problems unless you solve problems

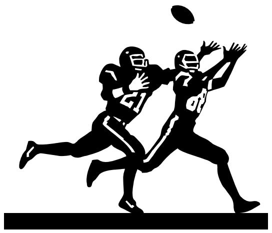
Must Practice Important Problem Solving Skills

Important to Build that Practice with Peers

Important to Have Expert Coaching

# Learning to Solve Problems Requires Practice

BUT



"Practice does not make perfect.
Only perfect practice makes perfect."
Vince Lombardi (expert on coaching)

Why is this is not perfect practice?

A block of mass m = 2.5 kg starts from rest and slides down a frictionless ramp that makes an angle of $\theta$= 25$^{o}$ with respect to the horizontal floor. The block slides a distance *d* down the ramp to reach the bottom. At the bottom of the ramp, the speed of the block is measured to be *v* = 12 m/s.

(a) Draw a diagram, labeling $\theta$ and d.

(b) What is the acceleration of the block, in terms of g?

(c) What is the distance *d*, in meters?

Robs students of practice making easy decisions
Does not reinforce motivation – reason to solve problems
Students do not practice linking to their existing information

## Original

A block of mass m = 2.5 kg starts from rest and slides down a frictionless ramp that makes an angle of $\theta = 25^o$ with respect to the horizontal floor. The block slides a distance *d* down the ramp to reach the bottom. At the bottom of the ramp, the speed of the block is measured to be $v$ = 12 m/s.

(a) Draw a diagram, labeling θ and d.

(b) What is the acceleration of the block, in terms of g?

(c) What is the distance *d*, in meters?

## Better

A 2.5 kg block starts from the top and slides down a slippery ramp reaching 12 m/s at the bottom. How long is the ramp? The ramp is at $25^o$ to the horizontal floor .

Practice making decisions

## Even Better

You are working with a design team to build a simple system to transport boxes from one part of a warehouse to another. In the design, boxes are placed at the top of the ramp so that they slide to their destination. A box slides easily because the ramp is covered with rollers. Your job is to calculate the maximum length of the ramp if the heaviest box is 25 kg and the ramp is at $5.0^o$ to the horizontal. To be safe, no box should go faster than 3.0 m/s when it reaches the end of the ramp.

Requires student decisions.
Practice making assumptions.
Connects to student reality.
Has a motivation (why should I care?).

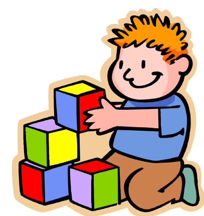
## Context Rich Problem

# The Dilemma

**Start with complex problems**
**so novice framework fails**

**Difficulty using strange new framework with challenging problems.**

**Why change?**



**Start with simple problems to learn expert-like framework.**

**Success using novice framework.**

**Why change?**

**Coaching is the necessary ingredient that allows students to work from the beginning solving complex problems that require an expert-like framework.**

# 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."

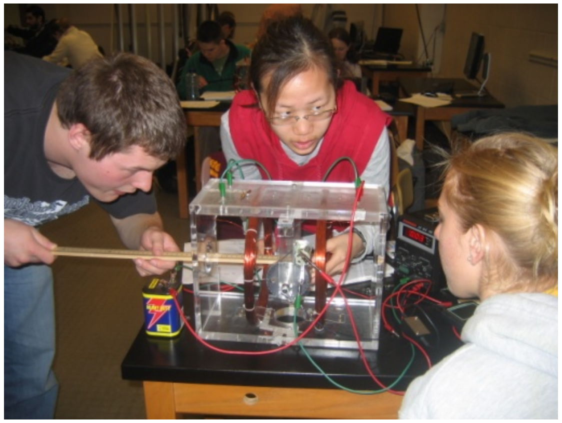
Rick Roesler Vice President, Handhelds Hewlett Packard

# Cooperative Group Problem Solving is an Implementation of Cognitive Apprenticeship

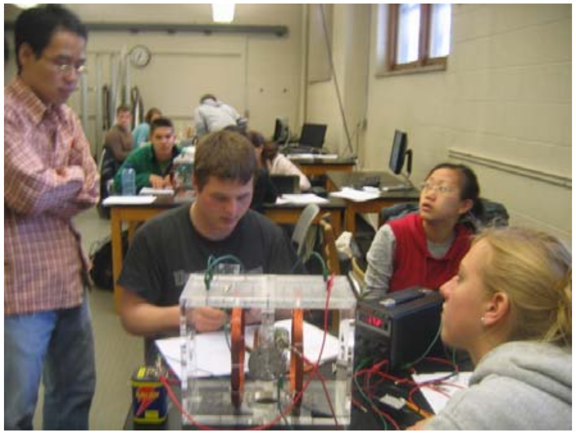
**There is no benefit in just having students work in groups.**

## Essential Elements

1. Practice an Organized Framework for Problem Solving
2. Problems that Require Using an Organized Framework
3. Cooperative Groups to provide coaching to students while solving problems
4. Appropriate Grading

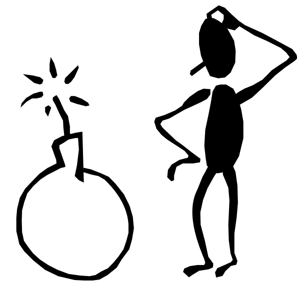


Peer coaching



Instructor coaching

# Identify Critical Failure Points



## 1. Inappropriate Tasks

- Problems require students to discuss problem solving.
  - ✓ Decisions to be made
  - ✓ Connecting  to personal ideas
  - ✓ Necessary to discuss the underlying concepts
- Something for all group members to contribute even if they don’t understand the physics.

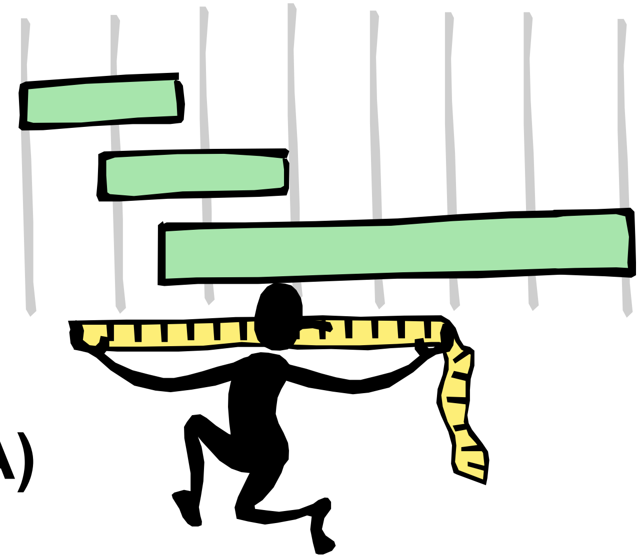
## 2. Poor Structure and Management of Groups

- Don’t allow any books or notes
- Structure that supports collaboration (not do it and compare)

## 3. Inappropriate Grading (0$^{th}$ Law of Education - If you don’t grade for it, they don’t learn it)

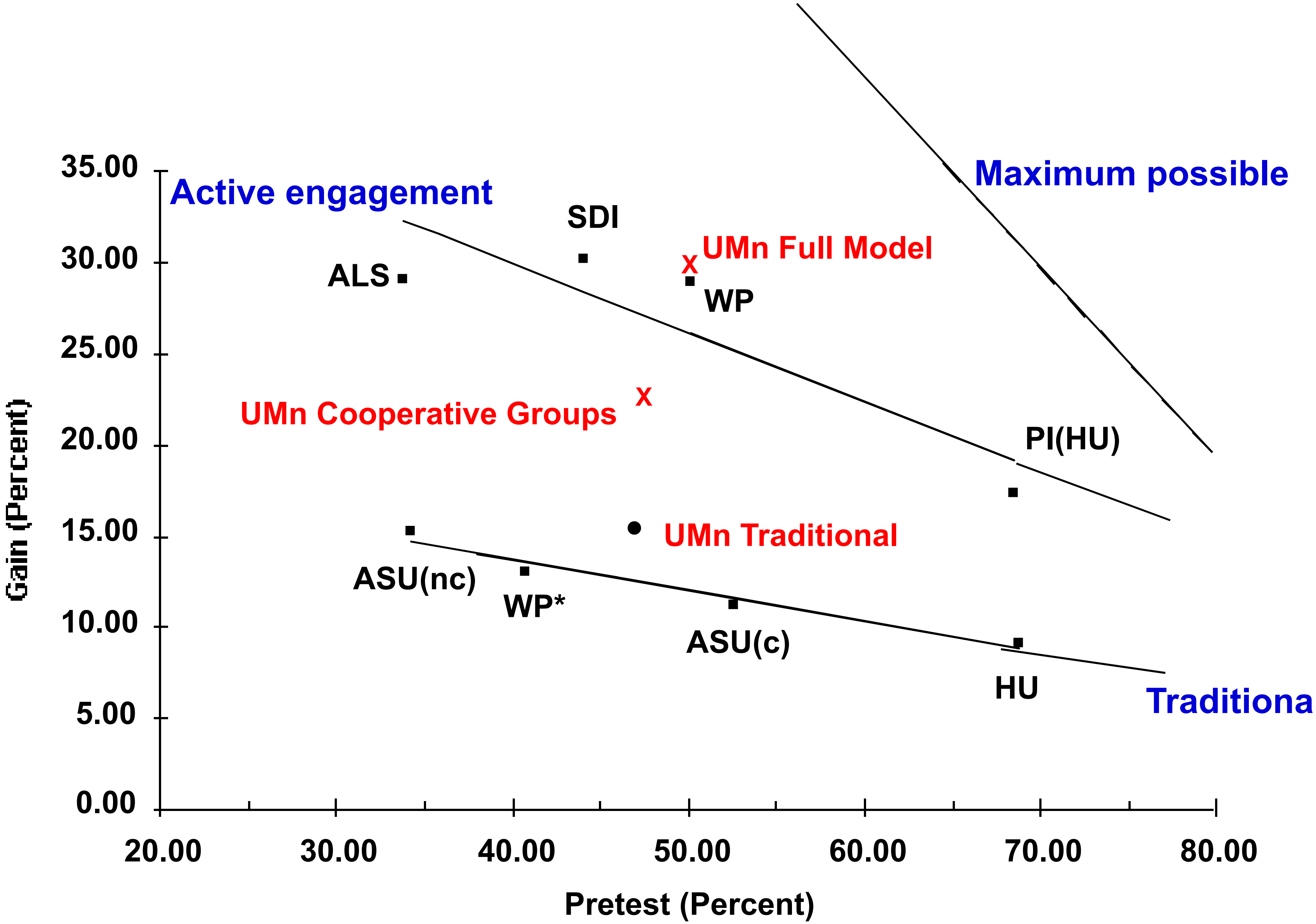
- Don’t penalize those who help others (no grading on the curve).
- Reward both individual and group learning.
- Reward the process not just the results.
- Practice tasks look like tests

# Assessment

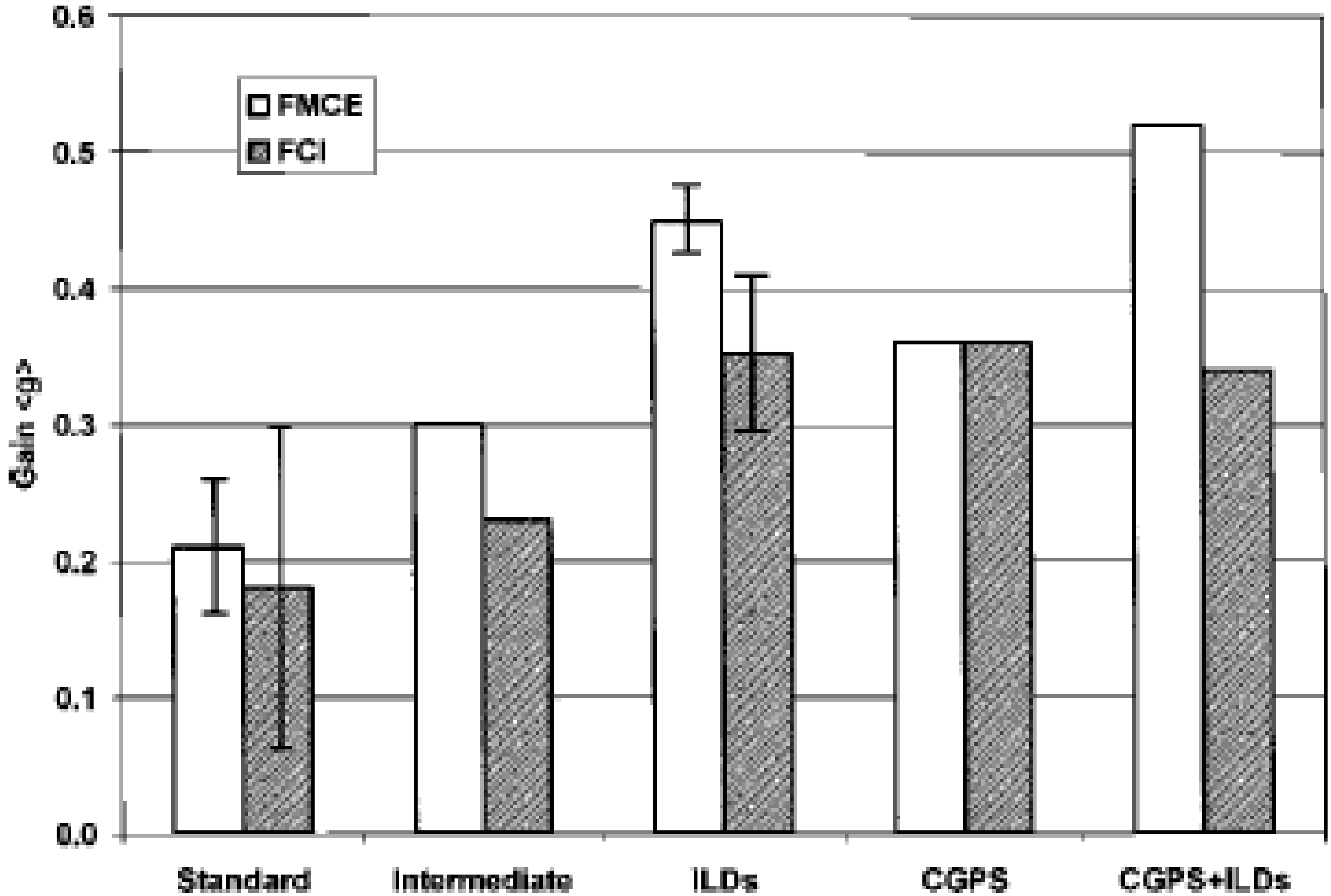


- Problem Solving Skill
- Drop out rate
- Failure rate
- National concept tests (FCI, BEMA)
- National attitude survey (CLASS)
- Math skills test
- What students value in the course
- Engineering student longitudinal study
- Faculty use
- Adoption by other institutions and other disciplines

# Gain on FCI (Hake plot)



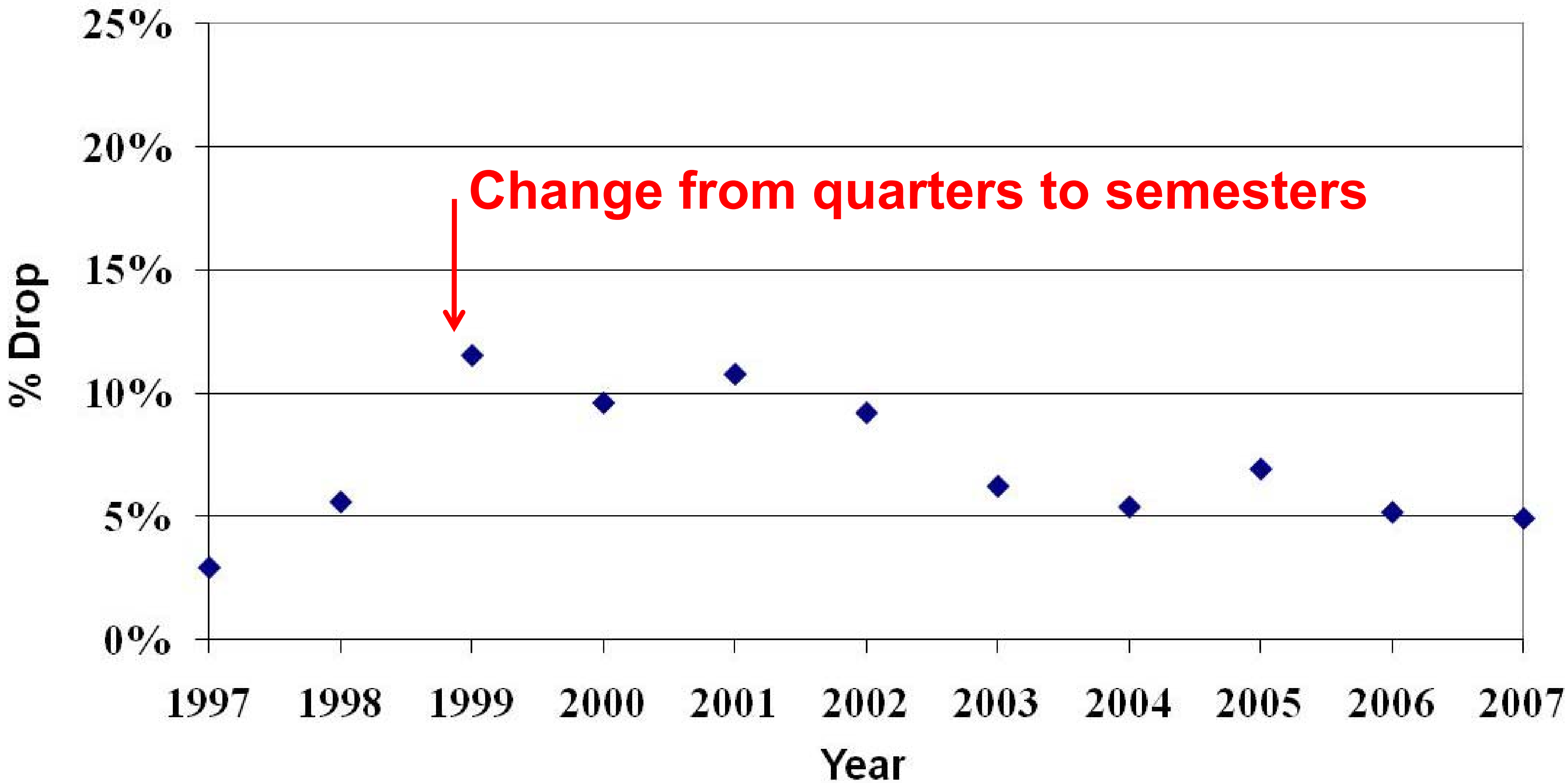
# Cooperative Group Problem Solving Teaches Concepts @ Rensselaer




**"Evaluating Innovation in Studio Physics"**

**Cummings, Marx, Thornton, Kuhl – AJP, 1999**

# Retention – Physics




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

# CGPS Propagates Through the Department

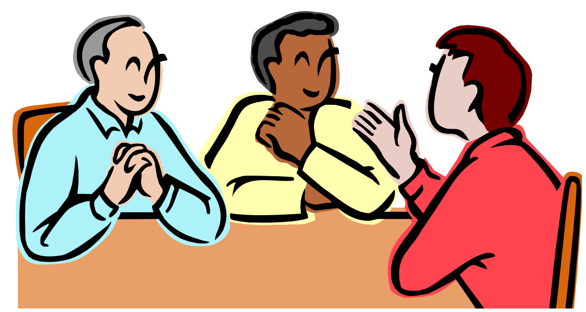
Algebra-based Intro Physics (24 different majors) 1987

Calculus-based Intro Physics (88% engineering majors) 1993

Intro Physics for Biology Majors Course 2003

Upper Division Physics Major Courses 2002

- Analytic Mechanics
- Electricity & Magnetism
- Quantum Mechanics



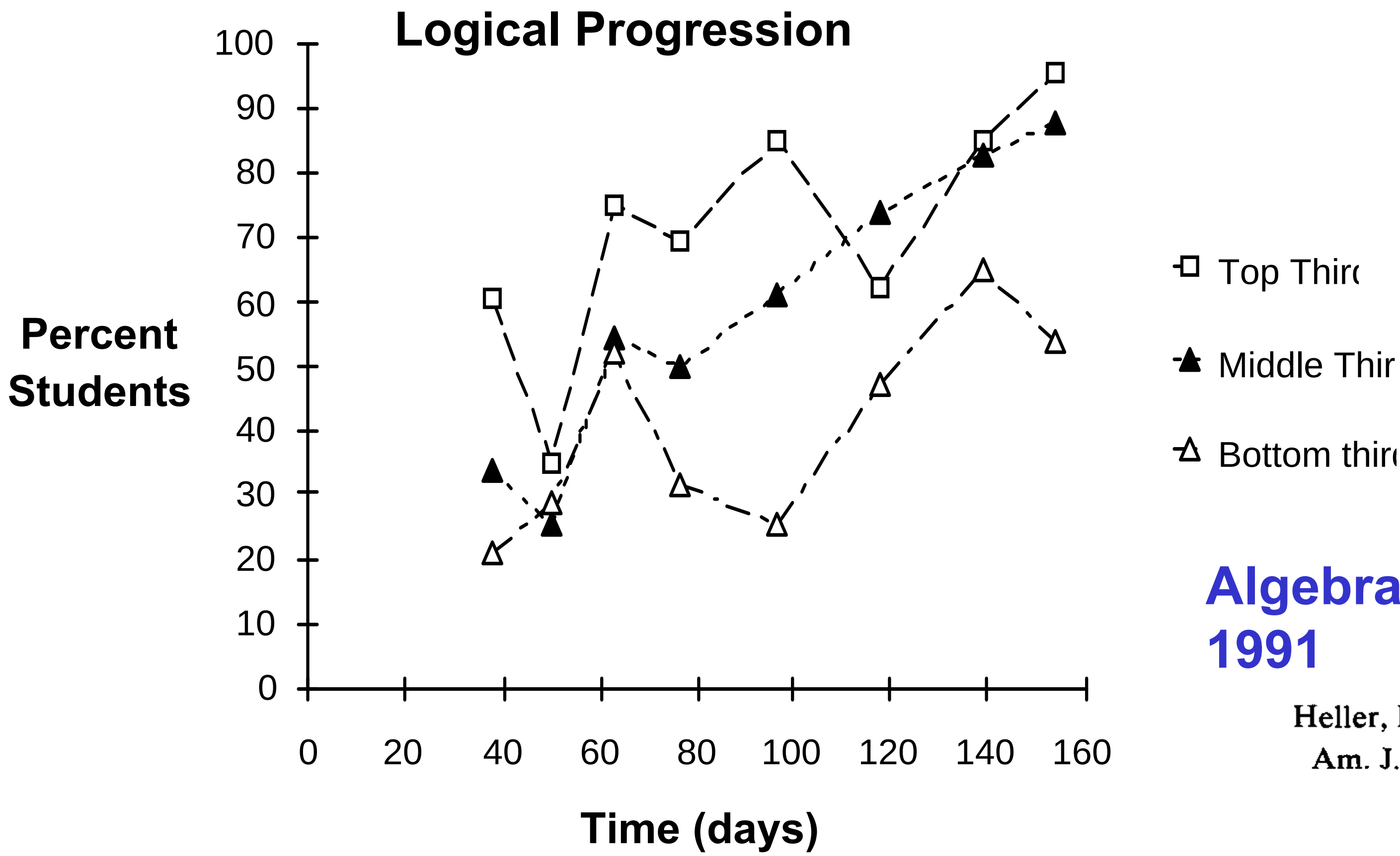
Graduate Courses 2007

- Quantum Mechanics

Budget constraints have prevented additional expansion in graduate courses

Mechanical Engineering 2010

# Improvement in Problem Solving




**Algebra based physics 1991**

Heller, Keith, and Anderson
Am. J. Phys., Vol. 60, No. 7, July 1992

**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?**

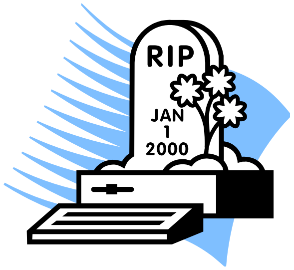
**Logical Progression - is the solution logically presented?**

**Appropriate Mathematics - is the math correct and useful?**

# Caution: Learning is Difficult

**Changing a deeply held way of thinking is traumatic**

**That trauma is the death of successful ideas and practices.**




**Response to emotional trauma**

**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 something 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 actually use this in my other classes and my internship."**

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

**Email just after Introductory Physics for Biology & Pre-Medical Students May, 2013**

**I am one of your former students in PHYS 1201W. I would like to thank you for your efforts in teaching us physics and guiding us through many difficult problems. I am currently studying for the MCAT and realized that your course, even though I hated it in the beginning, has helped me think critically and work through problems in an organized manner.**

**Have a great summer and best wishes,**
**Nhat**

**FCI pre- 50%, FCI post- 83%**
**CLASS pre – 33%, CLASS post – 58%**
**83% on first quiz – 88% on final exam problems (A)**

**Entire class average**
**FCI pre – 43%, FCI post – 69%**
**CLASS pre – 59%, CLASS post – 60%**
**Final exam problems – 65% (C+)**

# 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