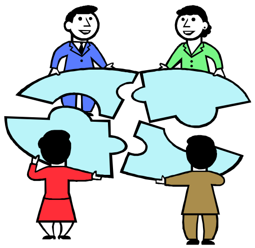
The University Student's 3 Rs

Reading, wRiting, and pRoblem solving

Using Context-Rich problems to facilitate learning



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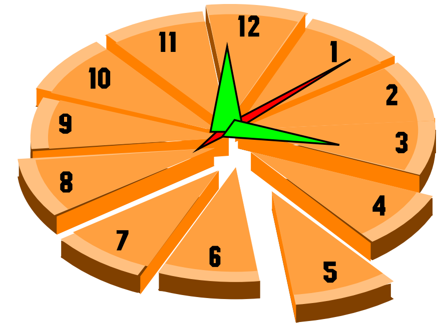
15 year continuing project to improve undergraduate education with contributions by:
Many faculty and graduate students of U of M Physics & Education
In collaboration with U of M Physics Education Group

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

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

A Guide for Discussion



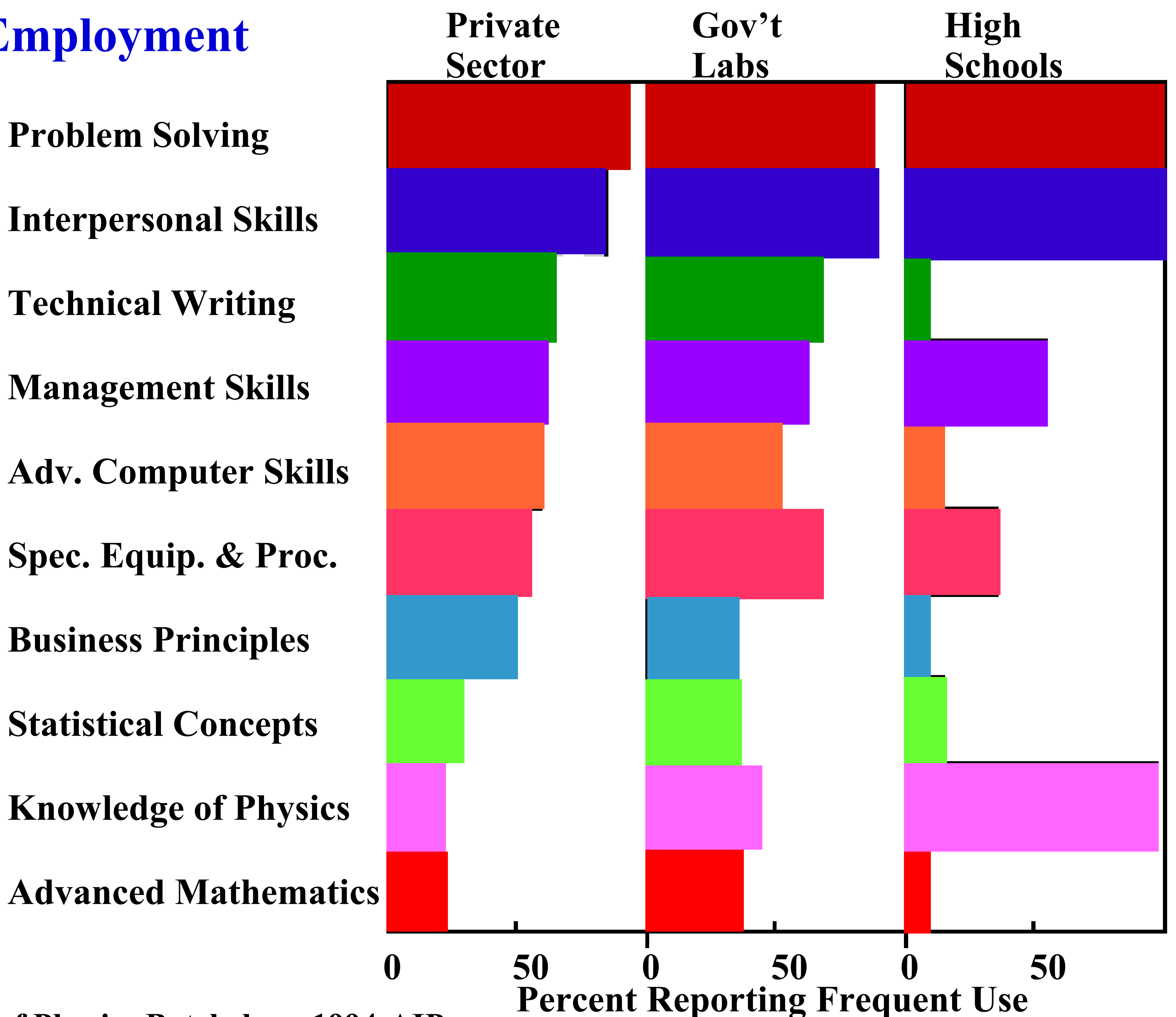
- ✓ **Goals for Instruction**
  - Why Solve Problems?
  - What are Problems?
  - How are Problems Solved?
- ✓ **Designing Problems**
  - What is Context-Rich?
  - Why?
- ✓ **Teaching Problem Solving?**
  - Possible Methods
  - Modeling a Framework
  - Supporting Real Problem Solving
  - Importance of Reading & Writing
- ✓ **How Well Does It Work**

Why Teach Students to Solve Problems?

- Society Wants It
- Industry Wants It
- Other Departments Want It
- Our Department Wants It

What is IT?

Employment



Survey of Physics Batchelors, 1994-AIP

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 tools

General-Purpose Heuristics

Not 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

Some Heuristics

Means - Ends Analysis

identifying goals and subgoals

Working Backwards

step by step planning from desired result

Successive Approximations

range of applicability and evaluation

External Representations

pictures, diagrams, mathematics

General Principles of Physics

TASK

Discuss the types of problems you assign in your classes. For your group list the common goals of these problems.

TIME ALLOTTED

5 minutes

PROCEDURES

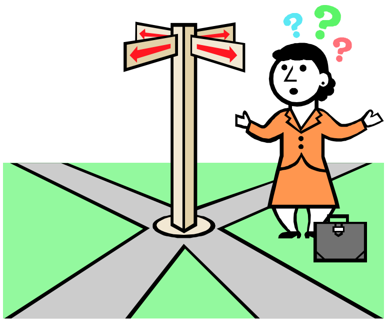
Form a group of 3 people
Choose one person as a reporter

Formulate **a response individually.**
Discuss **your response with your partners.**
Listen **to your partners' responses.**
Create **a new group response through discussion.**

Solving Problems Requires Conceptual Knowledge:

From Situations to Decisions

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



Students must be taught *explicitly*

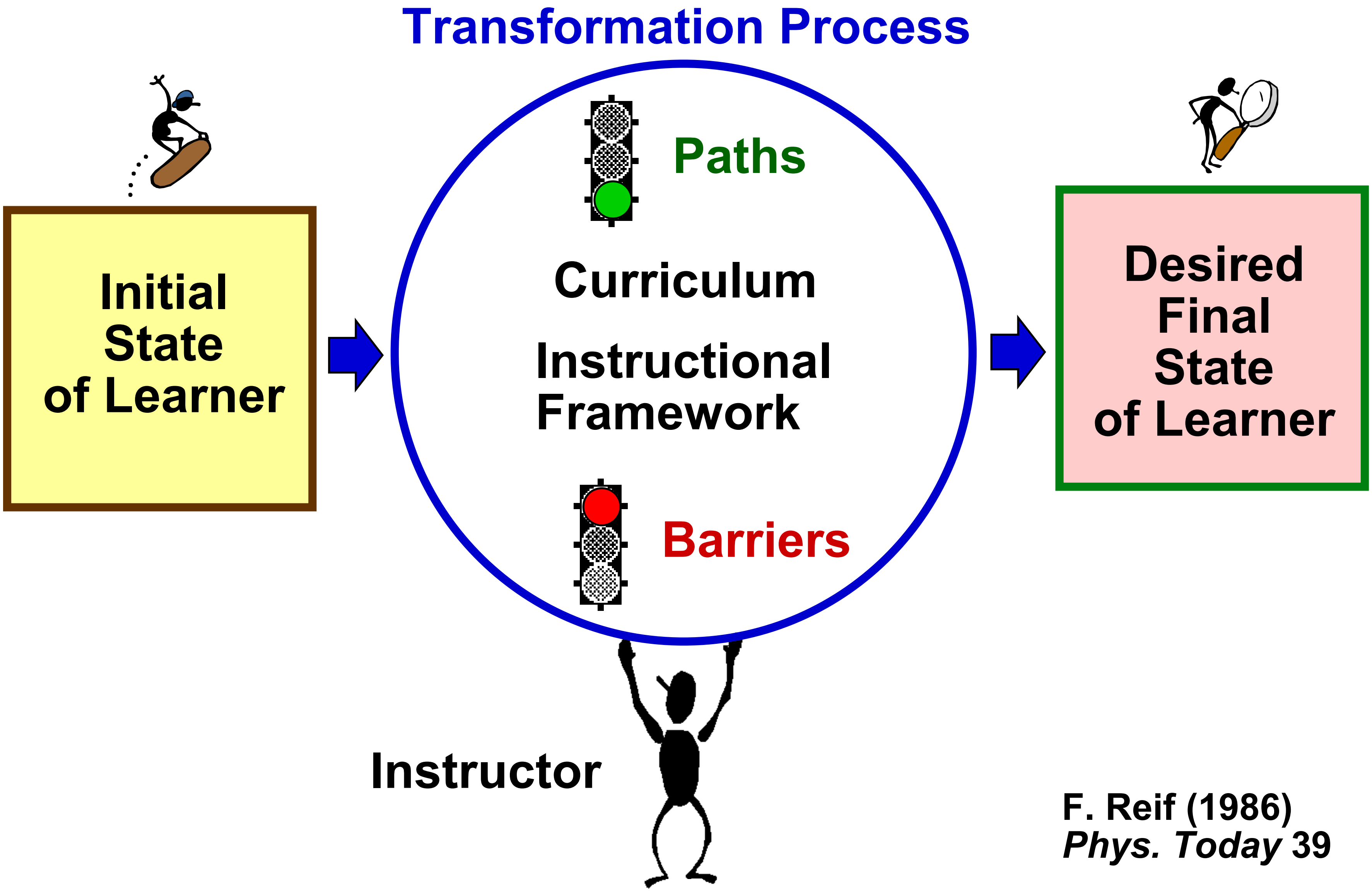
The difficulty -- major misconceptions, lack of metacognitive skills, no heuristics

Problem Solving Requires

Metacognative Skills

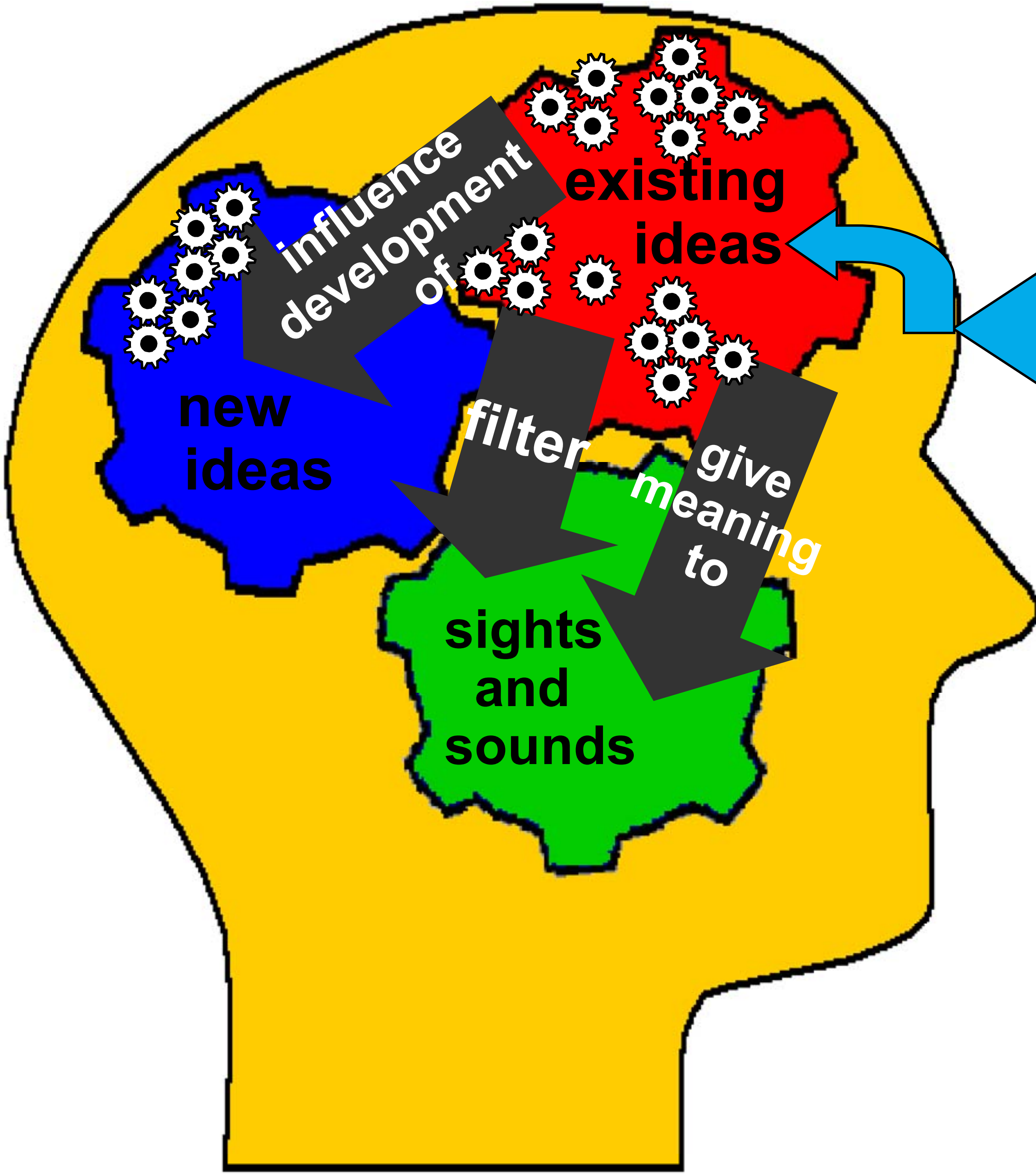
- Managing time and direction
- Determining next step
- Monitoring understanding
- Asking skeptical questions
- Reflecting on own learning process

Procedure for Change



F. Reif (1986)
Phys. Today 39

Cognitive Apprenticeship Instruction



Learning in the environment of expert practice

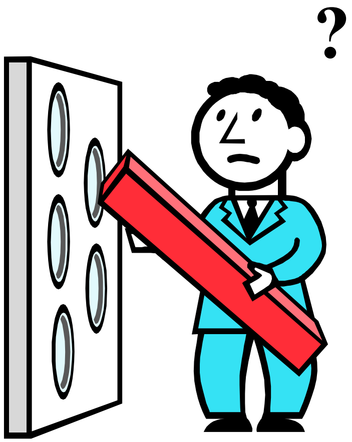
model

coach

fade

Collins, Brown, & Newman (1990)

Initial State of the Learner



Students have Misconceptions about

A Field of Knowledge

The Process of Learning

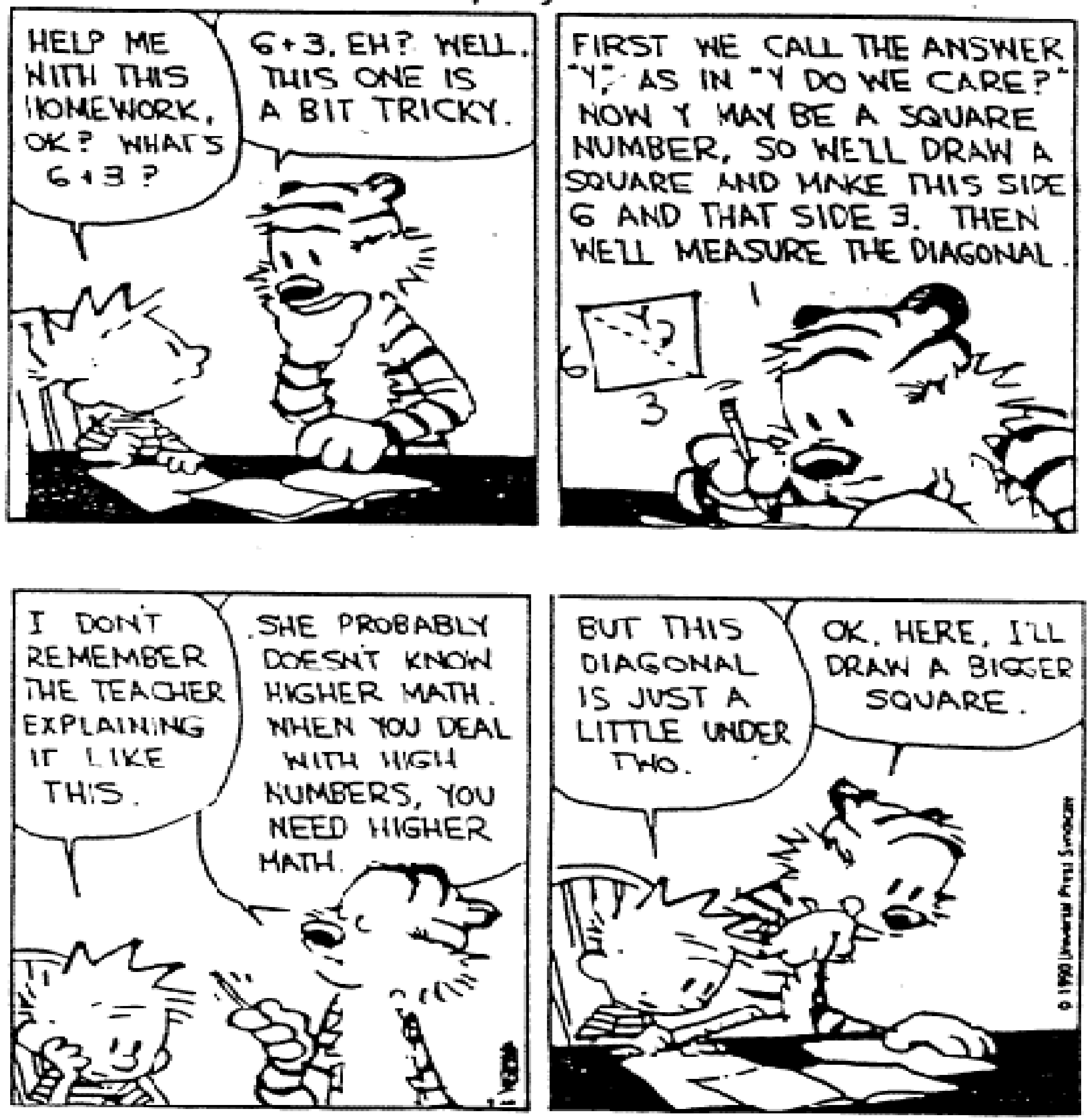
The Process of Problem-solving

The Content of Your Field

All combine to make it difficult for students to solve problems.

Not the same as “getting a problem right”.

Calvin and Hobbes / By,Bill Watterson

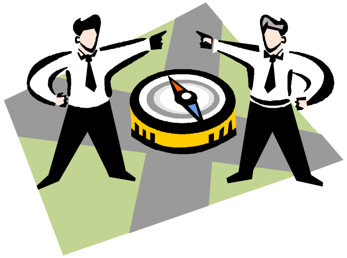
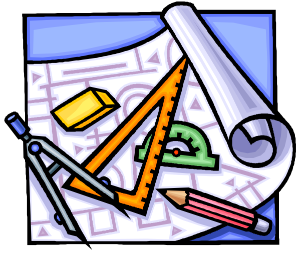
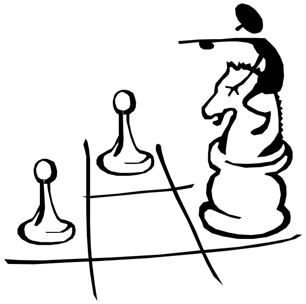


Appropriate Problems for Practicing Problem Solving

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

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

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

2. **The problems must be designed so that**

   - **the major problem solving heuristics are required (e.g. a situation requiring an external representation);**

   - **several decisions are required to make in order to accomplish the task (e.g. several ways to approach the problem);**

   - **the problem cannot be resolved in a few 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.

The Problem with Traditional Physics Problems

- Few decisions necessary
- Little visualization necessary
- Can usually be solved by manipulating equations
- Can often be solved without knowing physics
- Disconnected from student's reality

The Monotillation of Traxoline

(attributed to Judy Lanier)

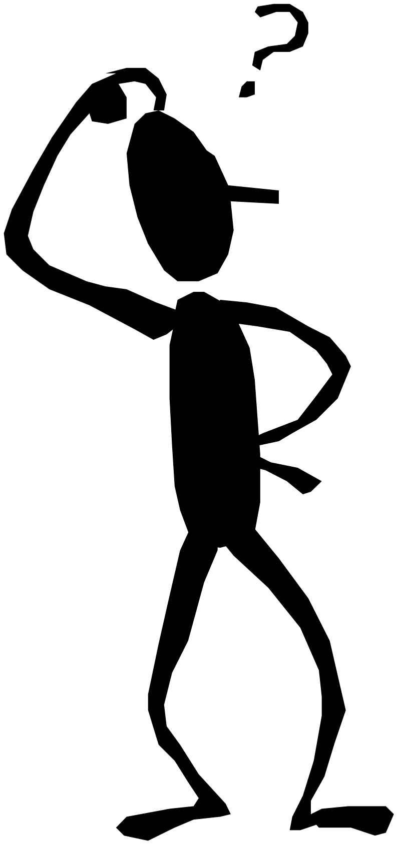
It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then brachter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

Answer the following questions.

1. **What is traxoline?**
2. **Where is traxoline montilled?**
3. **How is traxoline quasselled?**
4. **Why is it important to know about traxoline?**

Do Students Practice Problem Solving?

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

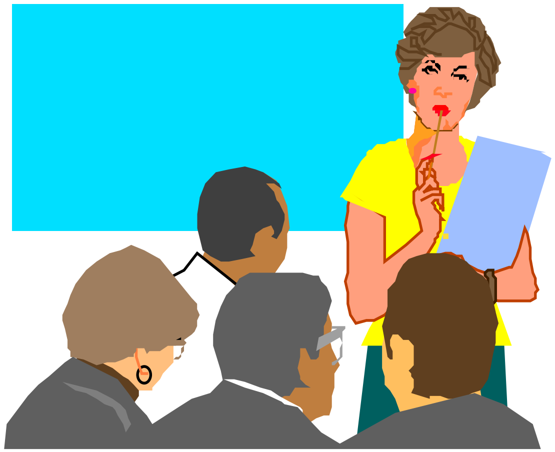


a. **What was the final velocity of the block?**

b. **What was the acceleration of the block?**

Textbook Problem

Task



- ✓ **Read at the following problem**
- ✓ **Discuss how you would go about solving it**

TIME ALLOTTED - 10 minutes

Discuss **your thoughts with your partners.**

Create **a group response through discussion.**

Context-Rich Problem

You have a summer job with an insurance company and are helping to investigate a tragic "accident." At the scene, you see a road running straight down a hill that is at of 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 the base of the cliff. A witness claims that the car was parked on the hill and began coasting down the road. He remembers that the car took 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. She tells you 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, she suspects foul play.

Expert "Real "Problem

Acquire Problem

↓ *derived cues*

Understand problem (visualization).
Decide tentatively what principles to try.

↓

Redescribe problem in terms of the field:
qualitative inferences, diagrams, and consideration of constraints
Categorize by possible approach

↓

Plan: Start with an expression of principles, work *backwards* from unknown.
Check -- enough information?

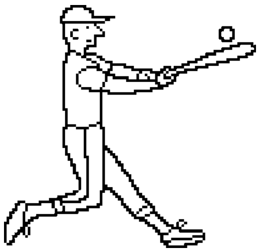
↓

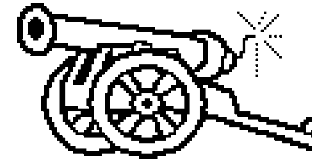
Execute the plan
Check consistency

↓

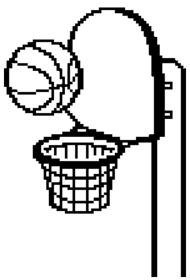
Check/Evaluate answer

Context-rich Problems

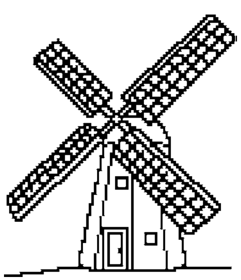




- **Each problem is a short story in which the major character is the student. That is, each problem statement uses the personal pronoun "you."**

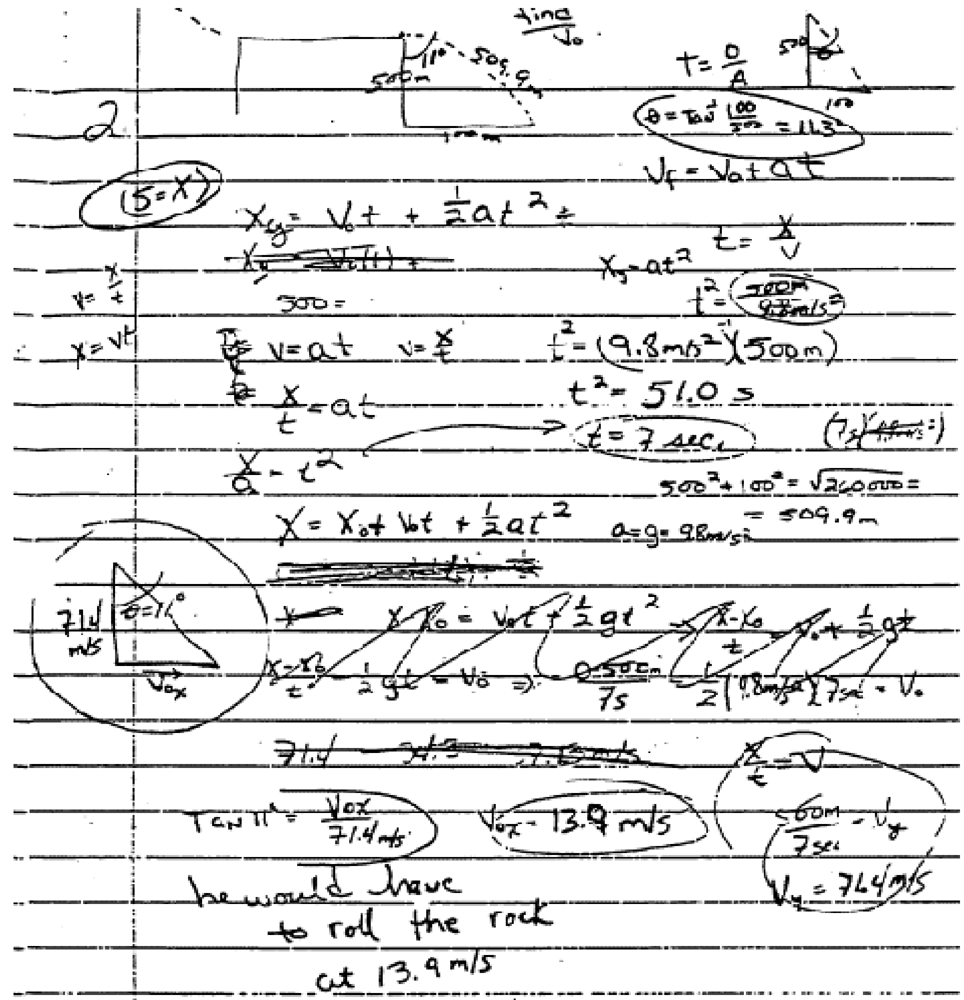


- **The problem statement includes a plausible motivation or reason for "you" to calculate something.**
- **The objects in the problems are real (or can be imagined) -- the idealization process occurs explicitly.**



- **No pictures or diagrams are given with the problems. Students must visualize the situation by using their own experiences.**
- **The problem can not be solved in one step by plugging numbers into a formula.**

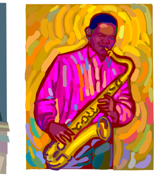
Because parents are concerned that children are taught incorrect science in cartoon shows, you have been hired as a technical advisor for the Cowboy Bob show. In this episode, Cowboy Bob is camped on the top of Table Rock. Table Rock has a flat horizontal top, vertical sides, and is 500 meters high. Cowboy Bob sees a band of outlaws at the base of Table Rock 100 meters from the side wall. The outlaws are waiting to rob the stagecoach. Cowboy Bob decides to roll a large boulder over the edge and onto the outlaws. Your boss asks you if it is possible to hit the outlaws with the boulder. Determine how fast Bob will have to roll the boulder to reach the outlaws.



Students need instructional support to solve problems

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

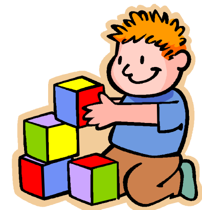
Let's get an answer

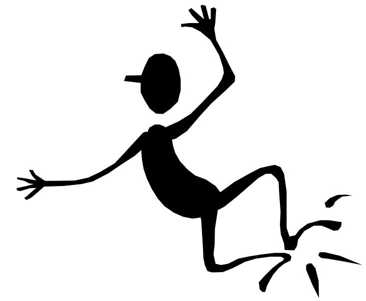
STEP 5

Evaluate the solution

Can this be true?

The Dilemma





Start with simple problems to learn expert-like strategy.

Success using novice strategy.

Why change?

Start with complex problems so novice strategy fails

Difficulty using new strategy.

Why change?

What Using Cooperative Groups Does for Teaching Problem Solving

1. Following a problem solving strategy seems too long and complex for most students.

   Cooperative-group problem solving allows practice until the strategy becomes more natural.

2. Complex problems that need a strategy are initially difficult.

   Groups can successfully solve them so students see the advantage of a logical problem-solving strategy early in the course.

What Using Cooperative Groups Does for Teaching Problem Solving

3. The group interactions externalize the planning and monitoring skills needed to solve problems allowing students to observe them. (Metacognition)

4. Students practice using the language of the field -- "talking physics."

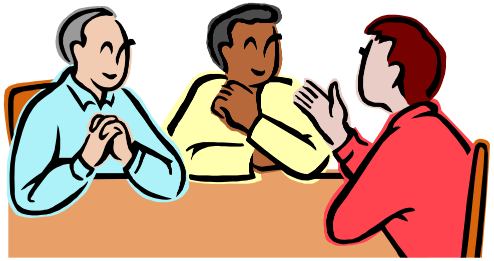
5. Students must deal with and resolve their misconceptions.

6. Coaching by instructors is more effective

External clues of group difficulties

Group processing of instructor input

Cooperative Groups



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

Cooperative Group Problem Solving

Emphasis: Fundamental Physics Principles & Problem Solving

Problem Design and Problem-solving Framework based on expert-novice research
Coaching based on collaborative learning research

Modify Lecture Style, Recitation and Laboratory

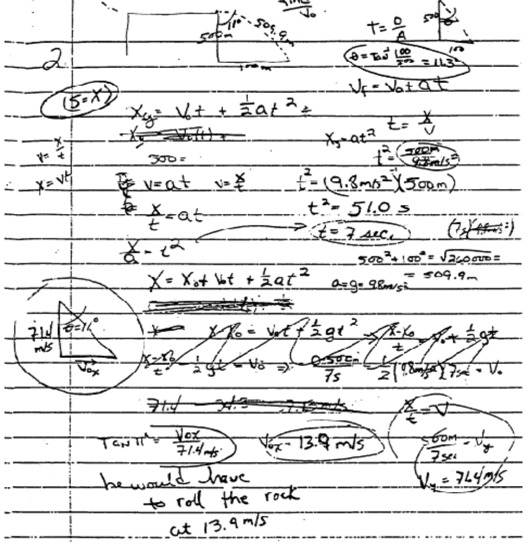
- **Lectures: MODEL concept construction in problem context and competent problem solving**
- **Recitation and Laboratory: COACH problem solving**

Scaffolding

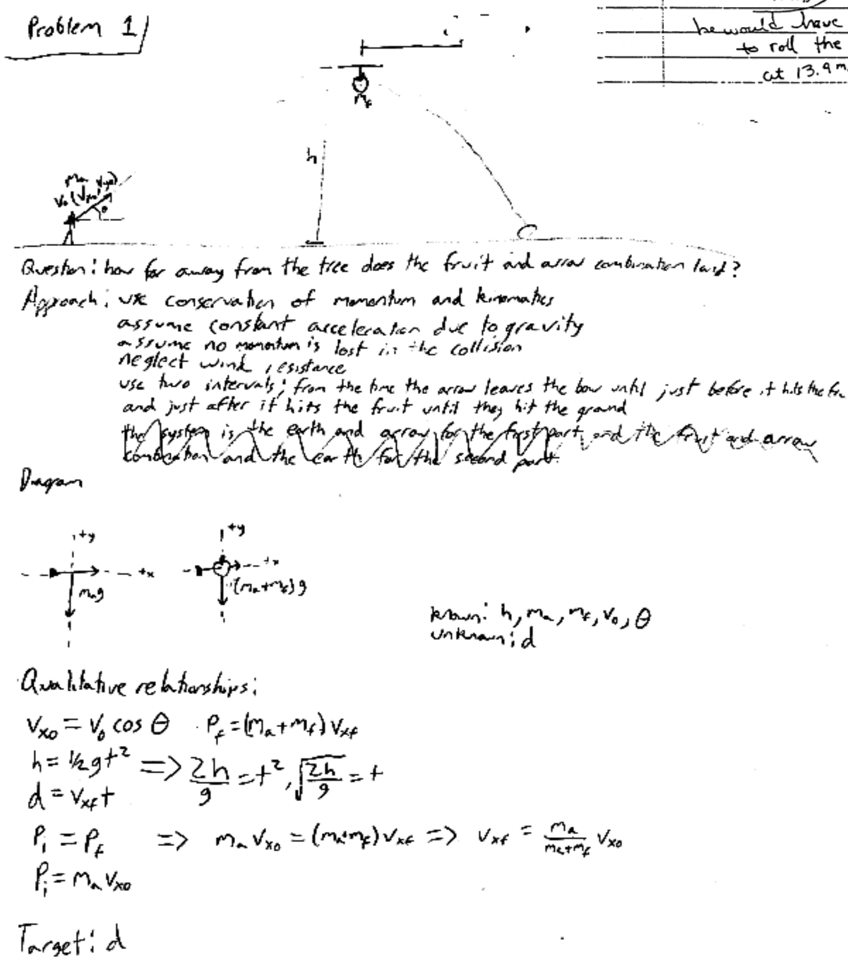
  - **Context-rich problems that require physics decisions**
  - **Explicit problem-solving framework**
  - **Structured cooperative groups**

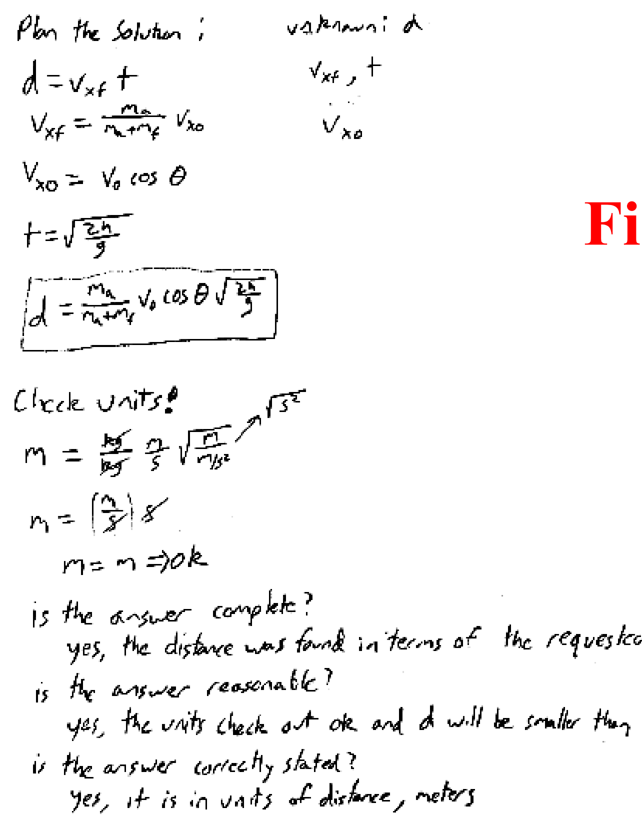
- **Remove scaffolding: FADE support**

Student Problem Solutions

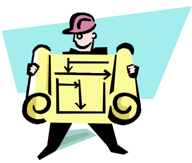


Initial State



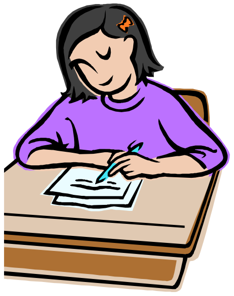


Final State



Importance of Laboratory Reports

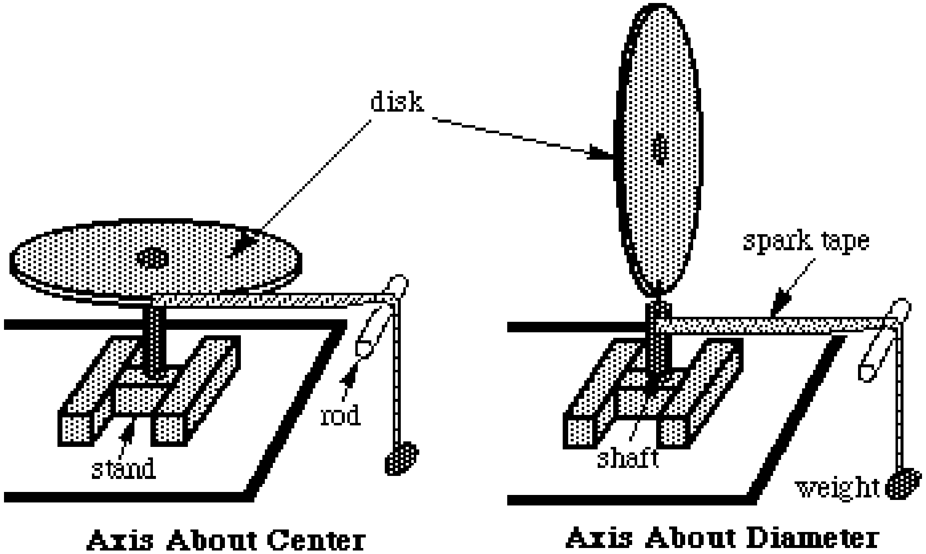
- **Learning through synthesis of information**
  - Students write reports to communicate to themselves and their instructor their understanding of:
    - » Logical reasoning
    - » Physics concepts
    - » Data analysis choices
    - » What they've learned
    - » What they've not learned



- **Clear & Concise technical communication**
  - Necessary for upper level courses in all majors
  - Sought-after skills by employers
    - » What is the decision
    - » Basis for the decision
    - » Consequences of the decision

Problem Solving Laboratories

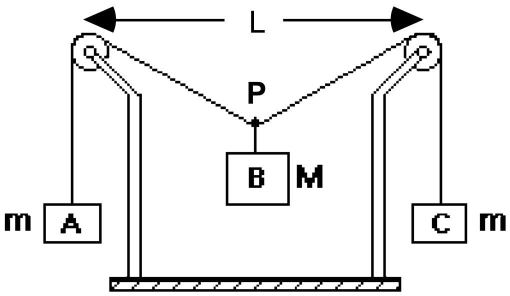
- Closely integrated with lecture & recitation
- Always context-rich problems
- Emphasize modeling real systems
- Work in Cooperative Groups
- Lab reports are short technical memos



- Each student hands in an individual laboratory report about every two weeks
- Each group member reports on a different problem
- TA assigns each student a problem at the end of each unit
- Student does not knows which problem will be assigned.
- Report is due in 2 days.

A Lab Problem:
Forces in Equilibrium
Mechanics Lab III, Problem #2

You have a summer job with a research group studying the ecology of a rain forest in South America. To avoid walking on the delicate rain forest floor, the team members walk along a rope walkway that the local inhabitants have strung from tree to tree through the forest canopy. Your supervisor is concerned about the maximum amount of equipment each team member should carry to safely walk from tree to tree. If the walkway sags too much, the team member could be in danger, not to mention possible damage to the rain forest floor. You are assigned to set the load standards. Each end of the rope supporting the walkway goes over a branch and then is attached to a large weight hanging down. You need to determine how the sag of the walkway is related to the mass of a team member plus equipment when they are at the center of the walkway between two trees. To check your calculation, you decide to model the situation using the equipment shown.



Guideline for grading laboratory reports

Problem Report:	Score
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	

Given to TAs & Students in Lab Manual

General Criteria for evaluating technical Reports

(Dr. Lee-Ann K. Breuch, Dept. Of Rhetoric, U of MN)

What is the subject? What information needs to be included?

- **Content:** Is the information appropriate, accurate, and complete?
- **Context:** What is expected in the discipline for this type of document?
- **Audience:** To whom is the document written? How will it be used?
- **Organization:** How can the information be best organized? Can the information be divided into sections?
- **Support:** What details, facts, and evidence can be used to illustrate main points?

Example of quality levels - Content

	Satisfactory	Adequate	Poor
Addresses content accurately and thoroughly	Accurate and complete technical information, including equations, explanations, theory, and data.	Accurate technical information, but has missed some important information.	Does not include accurate or complete information.
Score	3	2	1

Example of quality levels - Support

	Satisfactory	Adequate	Poor
The paper has appropriate support for statements	Has necessary illustrations or figures. Refers to appropriate readings, theories, & relevant background information; includes relevant graphs & tables; with proper labeling & cross-references figures, tables, & graphs.	Has appropriate readings & background information, but does not use clear logic; has tables & graphs but they are not always labeled or cross-referenced.	Does not include necessary support in the form of logic, background information, tables, or graphs. No labeling, & cross-references.
Score	3	2	1

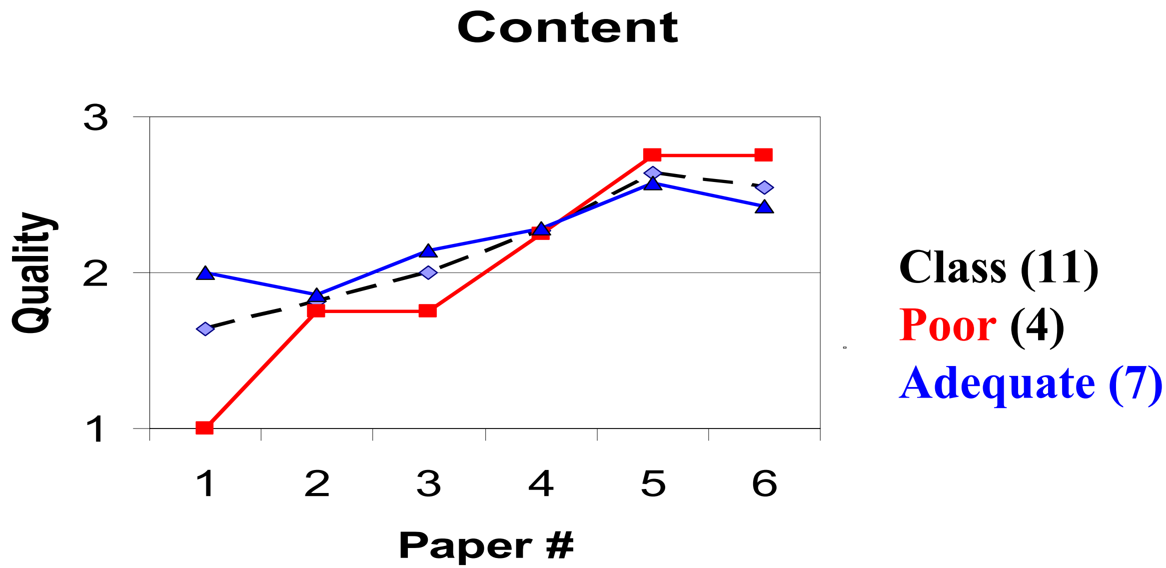
Example – Content & Support

Satisfactory:

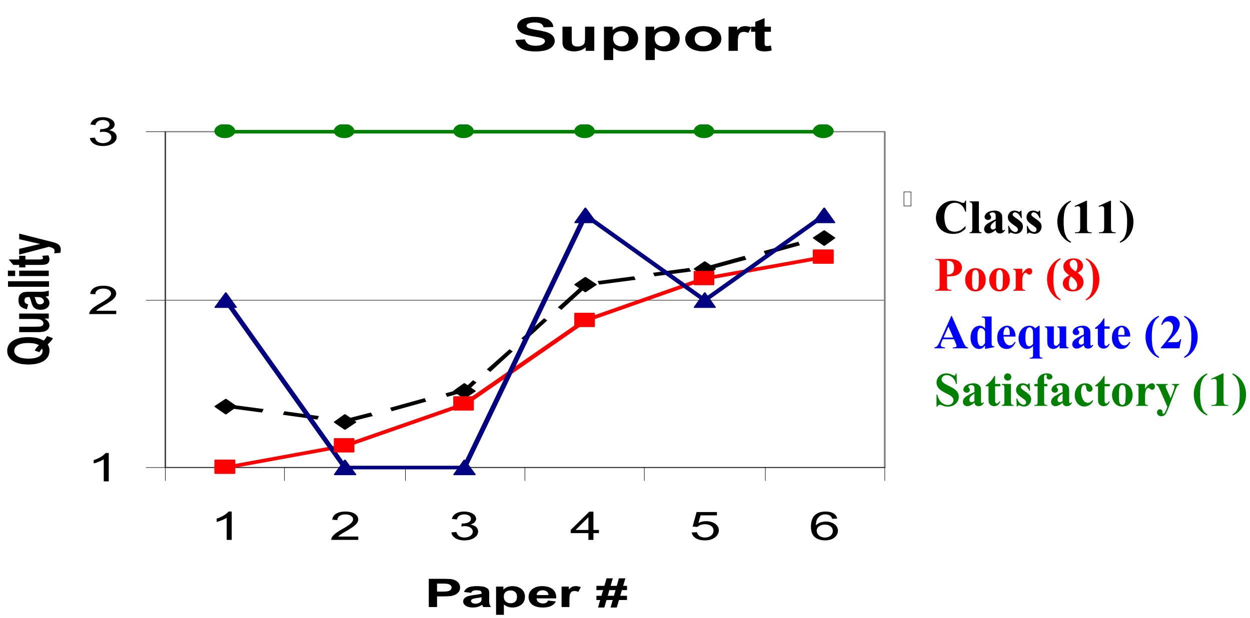
- **While the beam was rotating we timed how long it took to make five revolutions. We did this to determine the angular velocity, ω. Once we knew ω we plugged that value into the equation $v = R\omega$, where R is the radius. Our group and I concluded that the linear velocity (v) of a point on the beam increases when the radius increases with a constant angular velocity. There is a graph at the end of the report that shows this relationship for easier understanding.**

Adequate content & support:

- **I observed that the acceleration is zero at the time where the cart switches from going up the track to down the track. This is what we predicted to happen. Our group ... The graph is a constant slope from left to right because the acceleration is always negative and this is why the graph is an upside down parabola. This lab has helped me understand ... The acceleration is always negative (in this respect) which is a little hard to comprehend at first but it was nice to observe this in lab.**



Content: What information needs to be included?



Support: What details, facts, and evidence are used?

Topic of paper number:

1) 1-D Kinematics

2) 2-D Kinematics

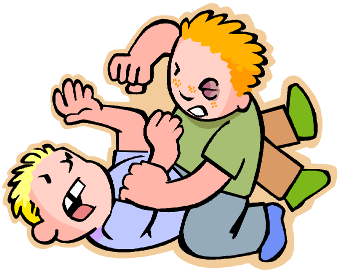
3) Forces

4) Conservation of Energy and Momentum

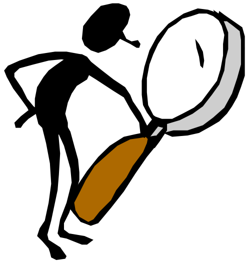
5) Rotational Kinematics

6) Rotational Dynamics

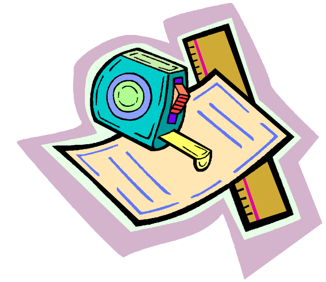
Why Group Problem Solving May Not Work



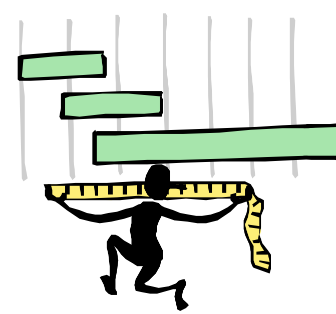
1. Inappropriate Tasks
2. Inappropriate Grading
3. Poor structure and management of Groups



Data



- Analysis of student exams
- Observation of student interactions
- Measures of conceptual understanding
  - FCI (Force Concept Inventory)
  - Other inventories
  - Open ended questions
  - Interviews
- Measures of hierarchical structure of physics
- Measures of student satisfaction
  - Surveys
  - Dropout rate
- Ease of implementation



The End

Please visit our website for more information:

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