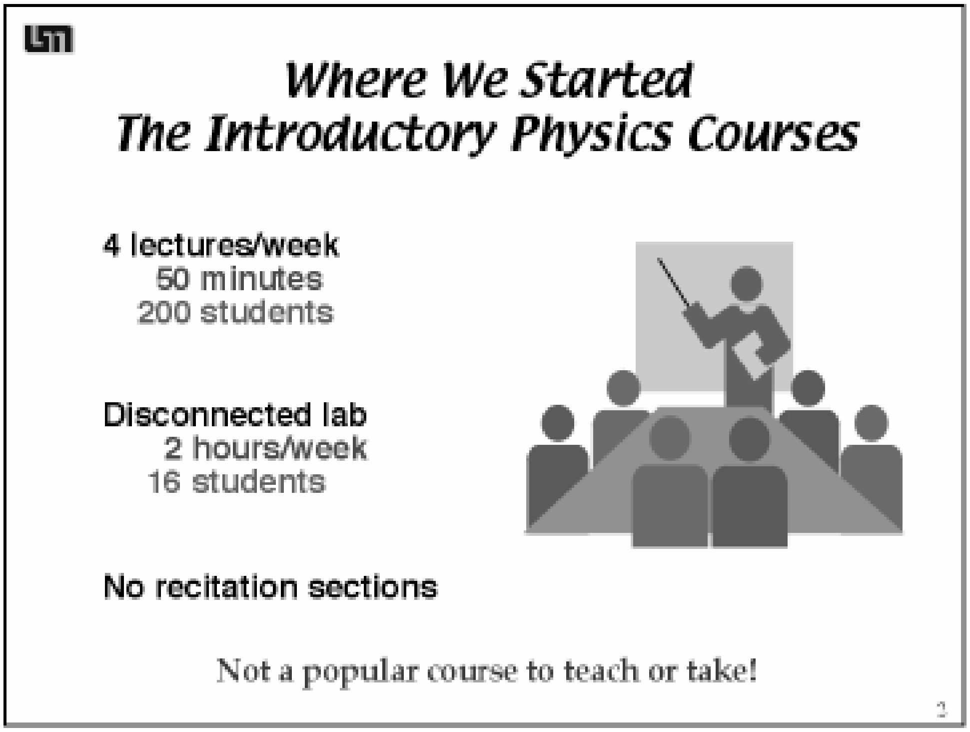
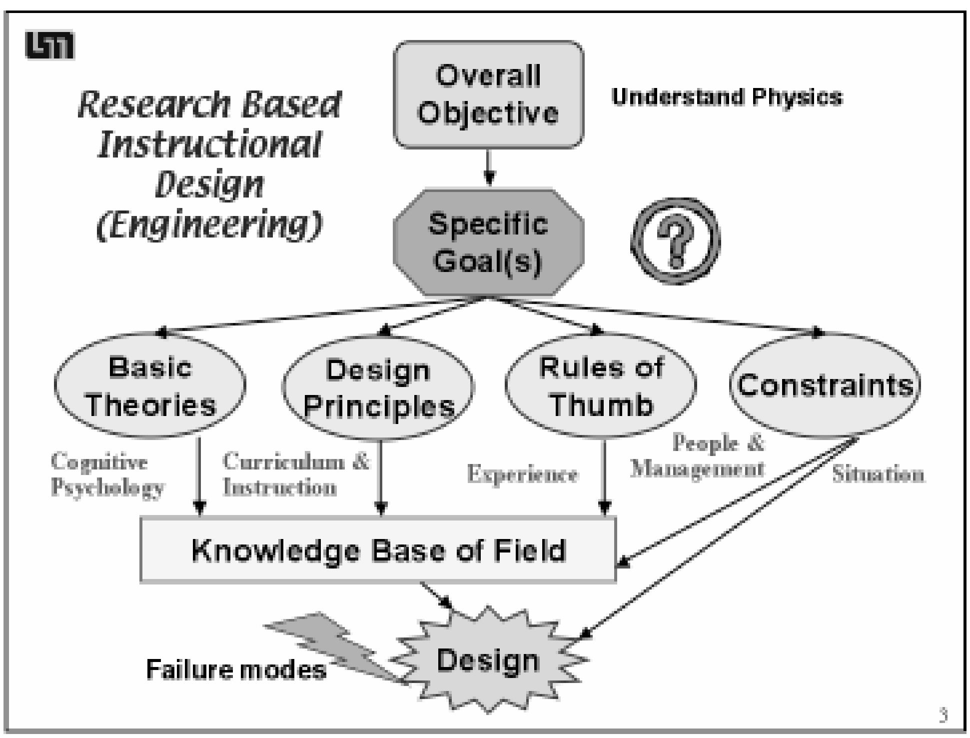
TA Orientation 2004

Activity 4. Rationale for UMN Model





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*

What Do Other Faculty Want?

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

- 4.7 Basic principles behind all physics (e.g., Newton's Laws)
- 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

- 4.8 Basic principles behind all physics
- 4.3 General qualitative problem solving skills
- 4.2 *Use biological examples of physical principles*
- 4.1 General quantitative problem solving skills
- 4.0 *Overcome misconceptions about physical world*
- 4.0 *Apply physics topics covered to real world situations*
- 4.0 *Know range of applicability of physics principles*
- 3.9 *Analyze data from physical measurements*

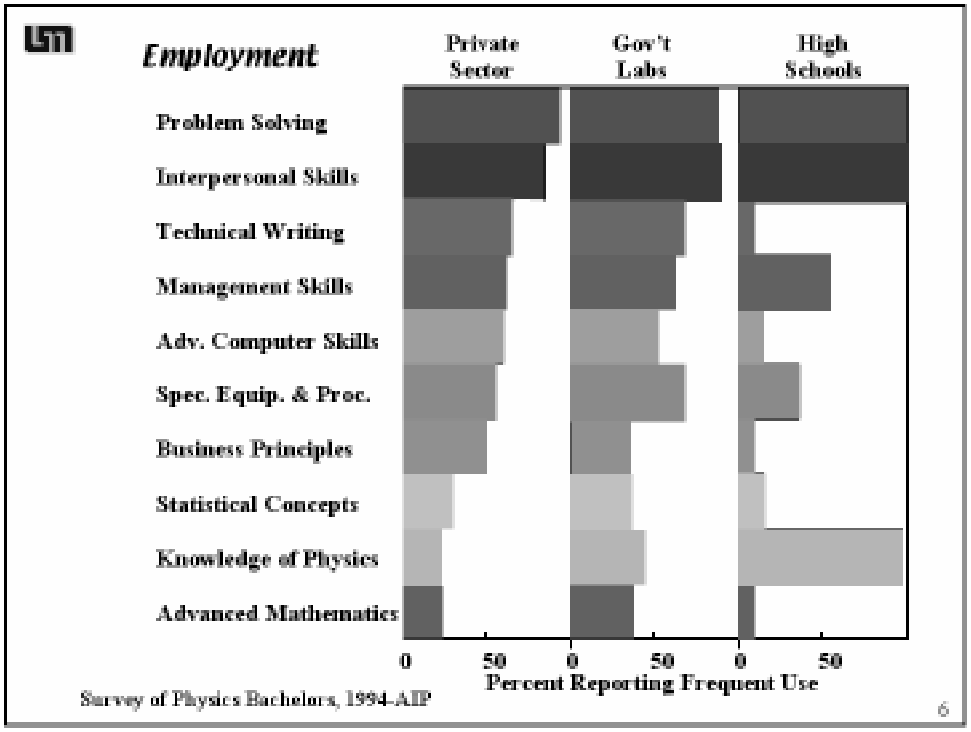
Modified survey in response to CBS Curriculum Committee

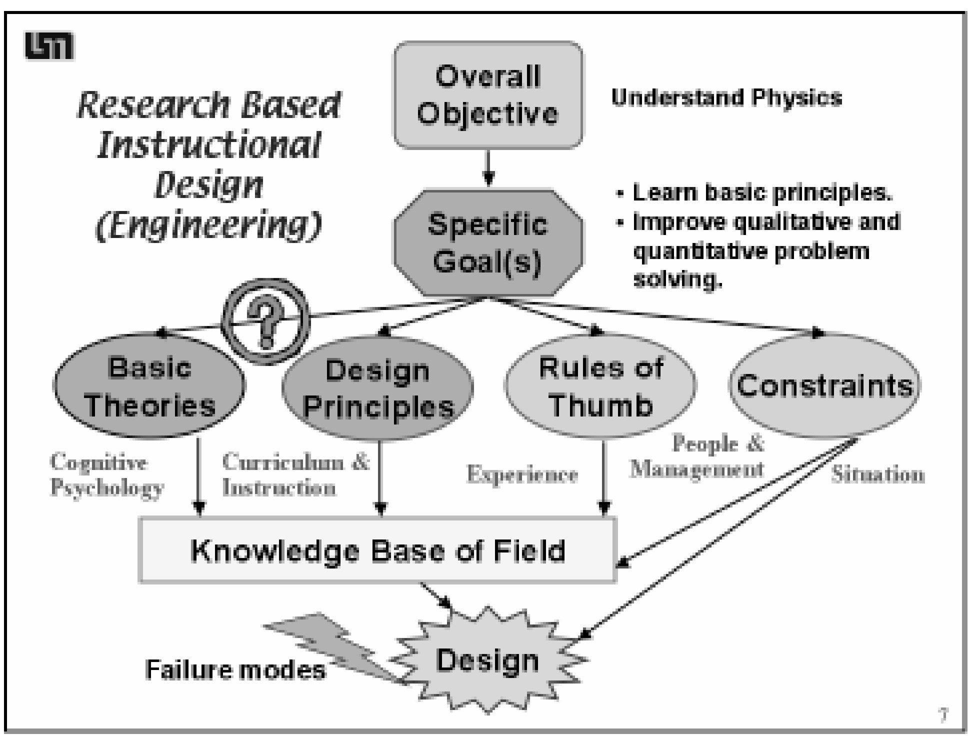
4

Goals Not Chosen

- Be familiar with a wide range of physics topics.
- Formulate and carry out experiments.
- Use modern measurement tools for physical measurements (e.g., oscilloscopes, etc.).
- Analyze data from physical measurements.
- Program computers to solve physics problems.
- Understand and appreciate "modern physics" (e.g., solid state, quantum mechanics, nuclei, etc.).
- Understand and appreciate the historical development and intellectual organization of physics.

5

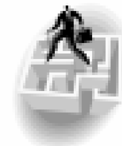

Employment
Private Sector
Gov't Labs
High Schools
Problem Solving
Interpersonal Skills
Technical Writing
Management Skills
Adv. Computer Skills
Spec. Equip. & Proc.
Business Principles
Statistical Concepts
Knowledge of Physics
Advanced Mathematics
0
50
0
50
0
50
Percent Reporting Frequent Use
Survey of Physics Bachelors, 1994-AIP
6


Research Based Instructional Design (Engineering)
Overall Objective
Understand Physics
Specific Goal(s)
• Learn basic principles.
• Improve qualitative and quantitative problem solving.
Basic Theories
Design Principles
Rules of Thumb
Constraints
Cognitive Psychology
Curriculum & Instruction
Experience
People & Management
Situation
Knowledge Base of Field
Failure modes
Design
7

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.



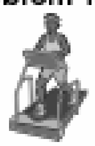
Problems are solved using tools.

General-Purpose Heuristics

Not algorithms

"Problem Solving Involves Error and Uncertainty"

A problem for your students is not a problem for you.

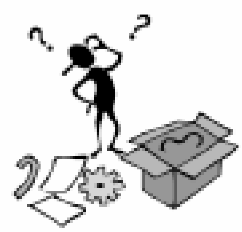


Exercise vs Problem

M. Martinez, Phi Delta Kappan, April, 1998

8

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

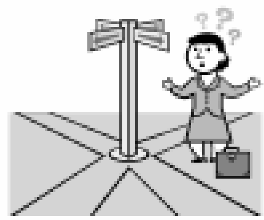
9

Solving Problems Requires

Conceptual Knowledge:

From Situations to Decisions

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



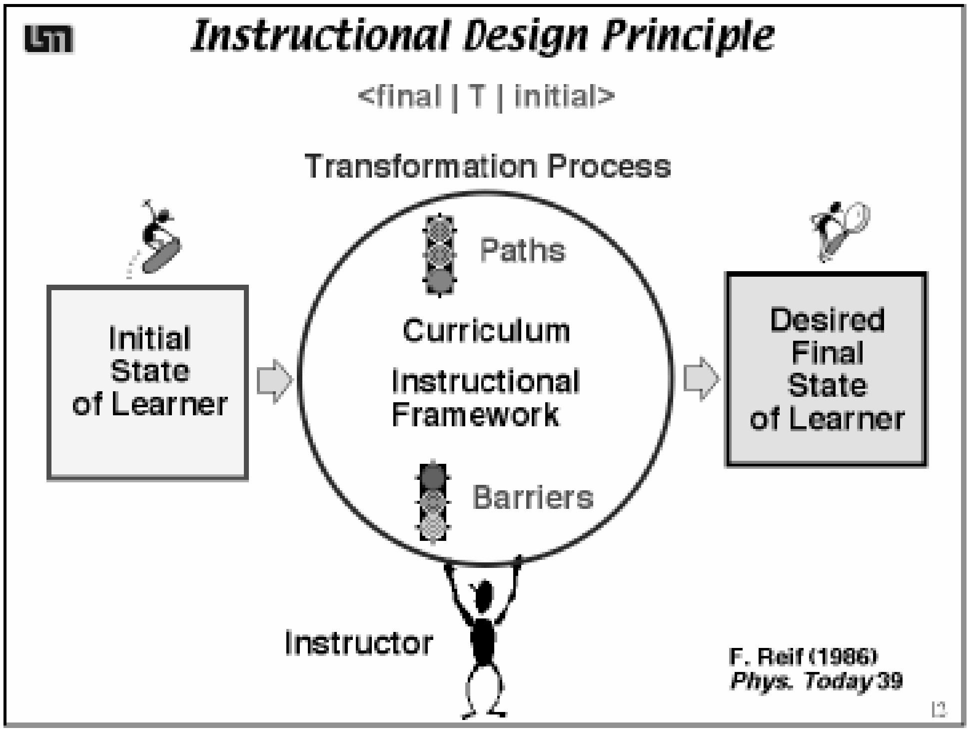
10

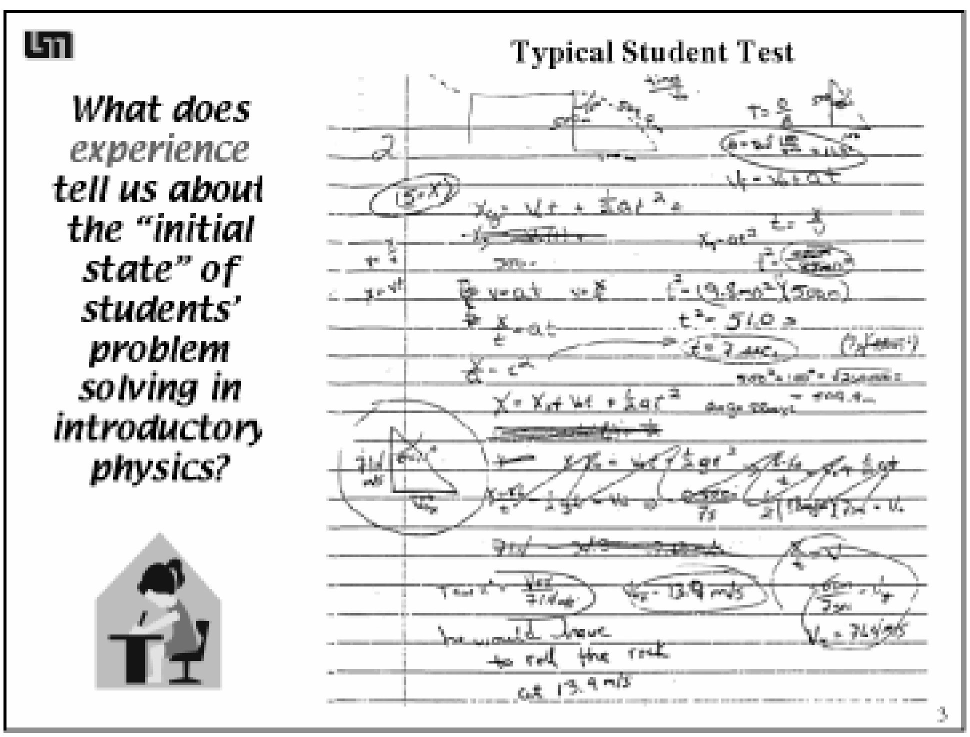
Solving Problems Requires

Metacognative Skills:

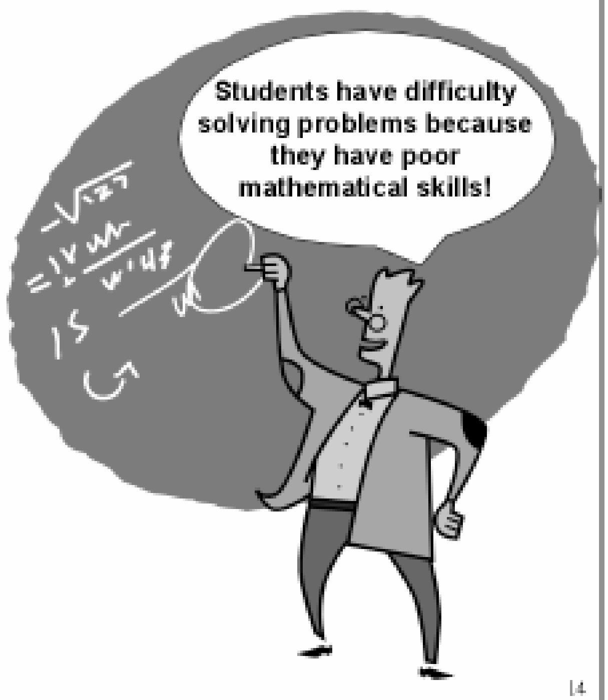
- Managing time and direction
- Determining next step
- Monitoring understanding
- Asking skeptical questions
- Reflecting on own learning process

11


Instructional Design Principle
<final | T | initial>
Transformation Process
Paths
Initial State of Learner
Curriculum
Instructional Framework
Desired Final State of Learner
Barriers
Instructor
F. Reif (1986) Phys. Today 39


What does experience tell us about the "initial state" of students' problem solving in introductory physics?
Typical Student Test

What is the Initial State of a Physics Learner?

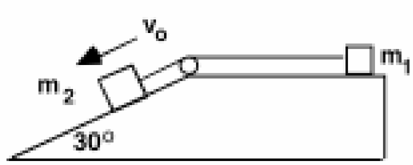


Do you agree with this professor? Why or why not?

14

Modified Atwood Machine Problem

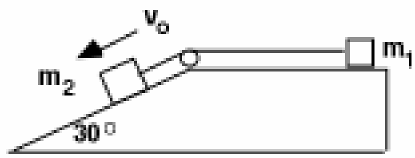
On Final Exam for calculus-based course, 1993



In the diagram shown above, block 1 of mass 1.5 kg and block 2 of mass 4 kg are connected by a light taut rope that passes over a frictionless pulley. Block 2 is just over the edge of the ramp inclined at an angel of 30°, and the blocks have a coefficient of sliding friction of 0.21 with the surface. At time t = 0, the system is given an initial speed of 11 m/s that starts block 2 down the ramp. Find the tension in the rope.

15

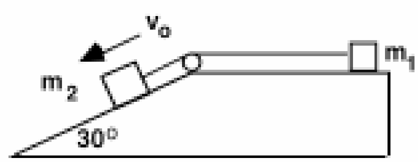
Atwood Solutions (N = 174)



Type of Solution	%
1. Correct or minor errors	29
2. Careless; many omissions; no sense of order	9
3. Incorrect Physics Approaches	52
4. Mathematics Problems	
a. Can't solve simultaneous equations	6
b. Trigonometry or algebra errors	3

16

Incorrect Physics Approaches: Atwood Machine



	%
a. $F_{unknown} = \sum F_{known}$ $T = F_{net} = f_1 + f_2 - m_2 g \sin\theta$	22
b. $\sum F = 0$ $\sum F = T - f_1 - f_2 = 0$	13
c. $F_{unknown} = ma$ $F = T = ma = m_2 g \sin\theta$	6
d. Incomplete, can't tell	11

17

Initial State of the Learner

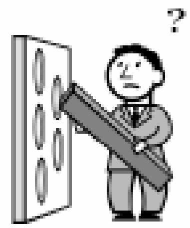
Students have Misconceptions about

The Field of Physics

Learning Physics

Nature

Problem-solving



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

Not the same as "getting a problem right".

18

Some References in Problem Solving

1916 - A. Binet & T. Simon, *Development of Intelligence in Children,* trans. E. S. Kite, Baltimore, Williams, and Witkins

1933 - J. Dewey, *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*

1957 - G. Polya, How to solve it: A new aspect of mathematical method, Princeton, NJ: Princeton University Press.

1972 A. Newell and H. Simon, *Human Problem Solving*, NJ: Prentice Hall

1980 - M. Chi, P. Feltovich, R. Glaser, *Categorization and Representation of Physics Problems by Experts and* Novices, *Cognitive Science,* 5, 121-152.

1980 - J. Larkin, J. McDermot, D. Simon, H. Simon, Expert and novice performance in solving physics problems, *Science*, 208, 1335-1342.

1980 - H. Simon, *Problem Solving and Education*, in D. Tuma and F. Reif (Eds), *Problem Solving and Education: Issues in Teaching and Research*

19

1979 - J. Larkin, & F. Reif, Understanding and teaching problem solving in physics, European Journal of Science Education, 1(2): 191-203

1985 - A. Schoenfeld, Mathematical problem solving. Orlando, FL: Academic Press.

1989 - D. Woods, Problem Solving in Practice, in D. Gabel ed, What Research Says to the Science Teacher, Vol. 5: Problem Solving

1992 - P. Heller, R. Keith, S. Anderson, Teaching Problem Solving Through Cooperative Grouping, Part 1: Groups versus individual problem solving. American Journal of Physics 60(7), 627-636.

1993 - J. Mestre, R. Dufresne, W. Gerace, P. Hardiman, & J. Touger, Promoting skilled problem-solving behavior among beginning physics students. Journal of Research in Science Teaching, 30(3), 303-317.

1994 - D. Maloney, Research on problem solving: Physics, in D. Gabel (Ed), Handbook of Research on Science Teaching and Learning (pp. 327-356). New York: Macmillan.

20

Misconceptions About Learning Physics

Professor explains what is required for that topic

Clear explanations which follow the textbook.

"I understand the concepts,
I just can't do the problems"

The test is exactly what the professor clearly explained.

Test problems follow
exactly worked examples.

"I can do the homework
but your test problems
are too different."

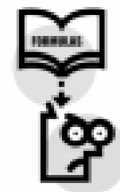
21

Students' Misconceptions About Problem Solving

You need to know the right formula to solve a problem:

- Memorize formulas;
  - Bring in "crib" sheets.
- Manipulate the equations as quickly as possible.

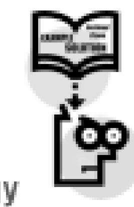
Novice "Plug-and-chug" Strategy



It's all in the sequence of mathematics:

- Memorize example solutions.
- Numbers are easier to deal with;
  - Plug in numbers as soon as possible.

Novice "Pattern Matching" Strategy



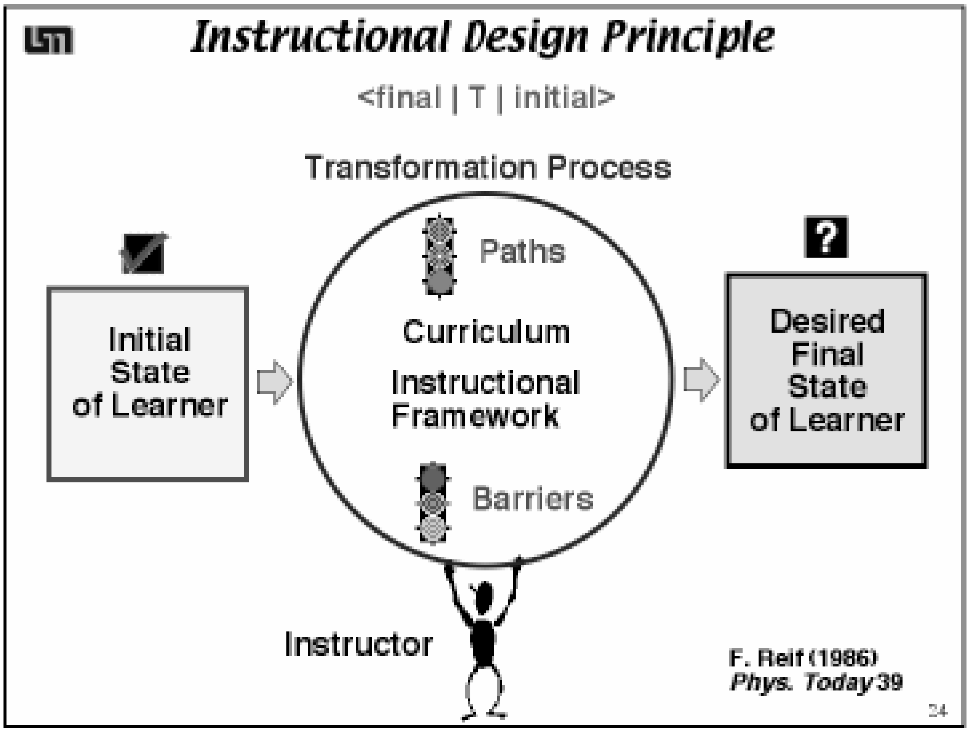
22

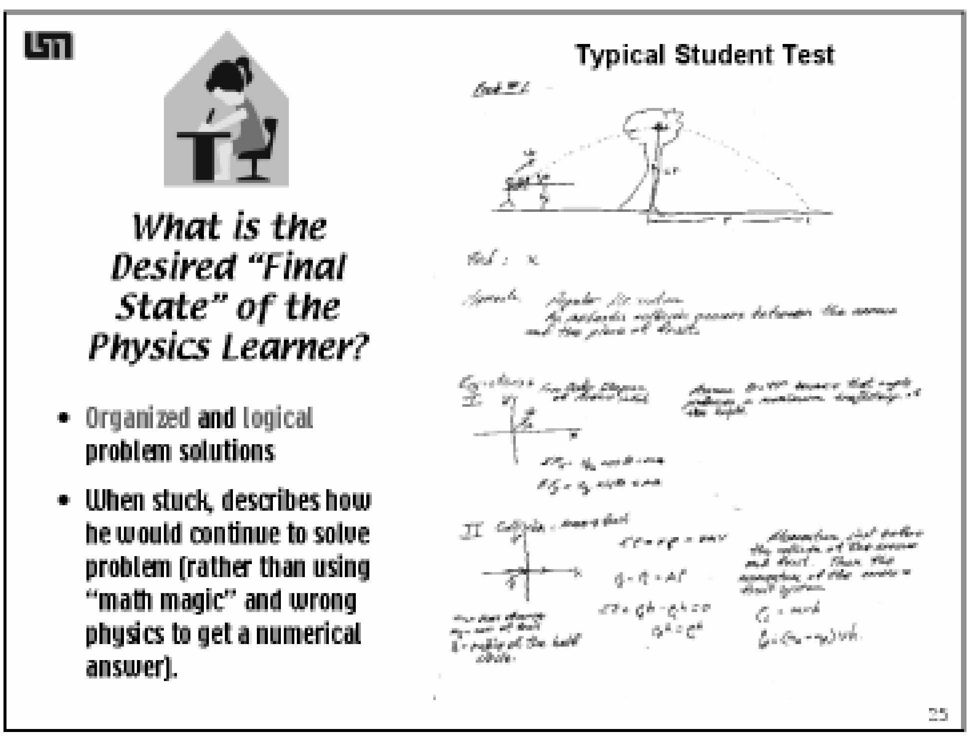
Initial State of the Learner

- Misconceptions about physics, learning physics, and problem solving
- Lack of metacognitive skills
- No problem-solving heuristics

Typical Student Test

23


Instructional Design Principle
<final | T | initial>
Transformation Process
Paths
Curriculum
Instructional Framework
Barriers
Initial State of Learner
Desired Final State of Learner
Instructor
F. Reif (1986) Phys. Today 39
24


What is the Desired "Final State" of the Physics Learner?
• Organized and logical problem solutions
• When stuck, describes how he would continue to solve problem (rather than using "math magic" and wrong physics to get a numerical answer).
Typical Student Test
25

From Novice to Expert Problem Solver

7 - 10 Years

Novice -- context-bound facts, features, rules
Every case is unique (plug-and-chug)

Advanced Beginner -- adds situational elements to rules
Patterns based on context (pattern matching)

Competent -- context-free rules applied to unique situations
Patterns based on rules

Proficient -- context-free rules applied to patterns of situations
Patterns based on situations

Expert -- context-free rules modified by situation pattern

26

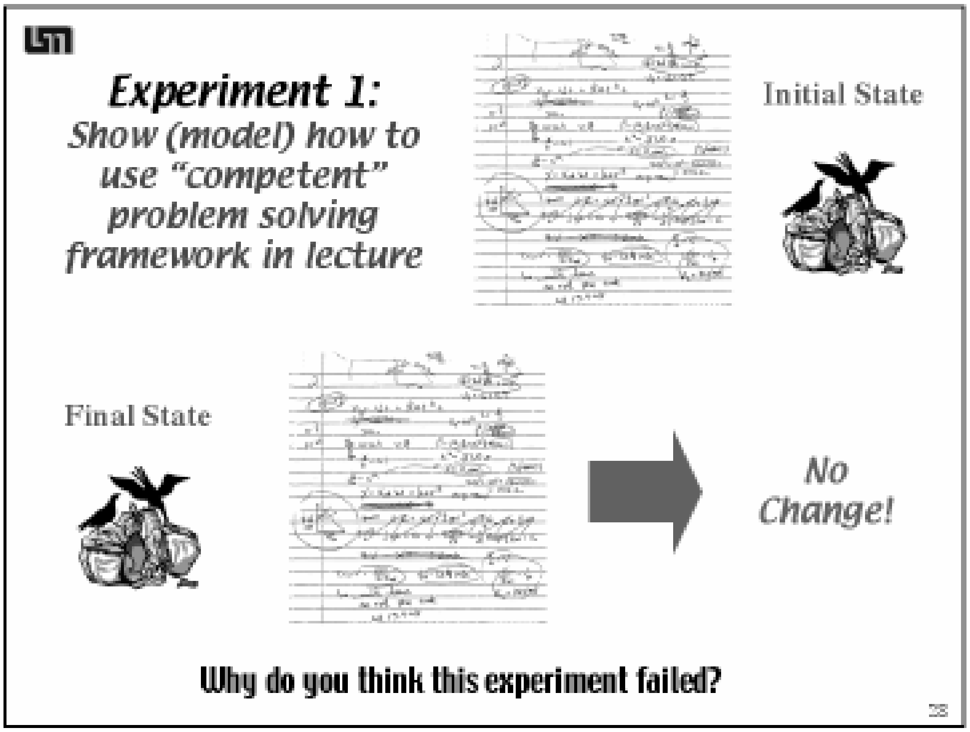
We can NOT expect students to become expert problem solvers in one year!

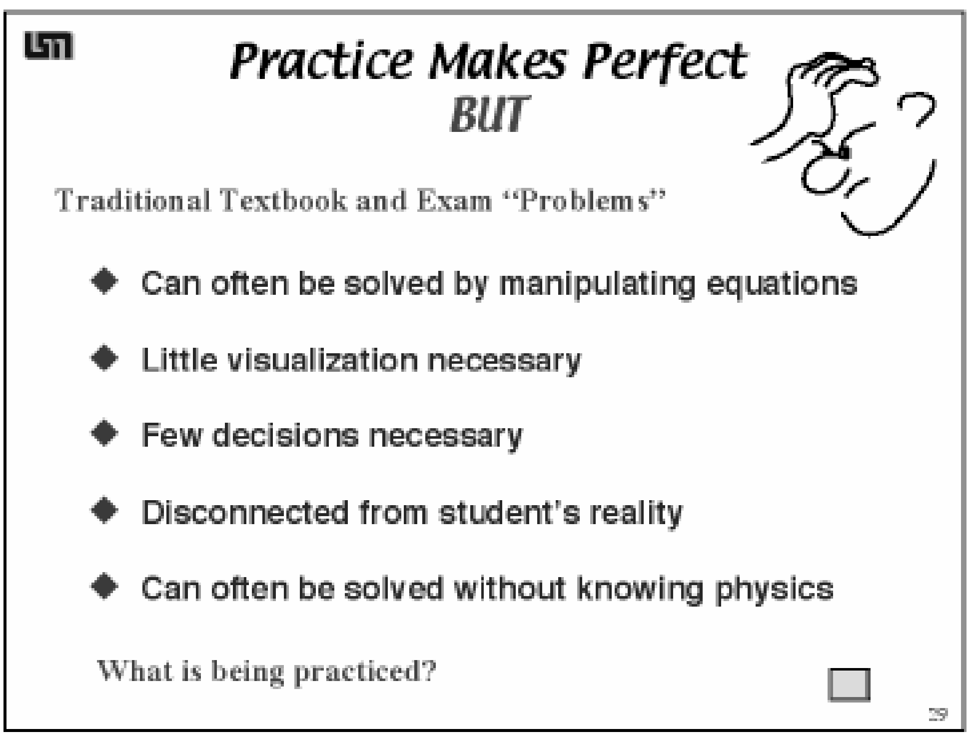
GOAL: Help student move along the continuum from novice or advanced beginners towards Competent problem solvers (patterns based on rules).

Students can learn a "competent" problem-solving framework that directs their efforts toward making connections both among physics concepts and between those concepts and the rest of their knowledge.

The framework should be a logical and organized guide to arrive at a problem solution. It gets students started, guides them to what to consider next, organizes their mathematics, and helps them determine if their answer is correct.

27


Experiment 1:
Show (model) how to use "competent" problem solving framework in lecture
Initial State
Final State
No Change!
Why do you think this experiment failed?
28


Practice Makes Perfect
BUT
Traditional Textbook and Exam "Problems"
Can often be solved by manipulating equations
Little visualization necessary
Few decisions necessary
Disconnected from student's reality
Can often be solved without knowing physics
What is being practiced?
29

This Textbook Problem Does NOT Reinforce 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?

Why?

31

Appropriate Problems for Problem Solving

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

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.

32

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 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, 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.

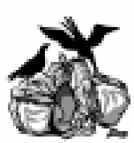
33

Experiment 2:

Show (model) "competent" problem solving framework in lecture and use context-rich problems.

Initial State

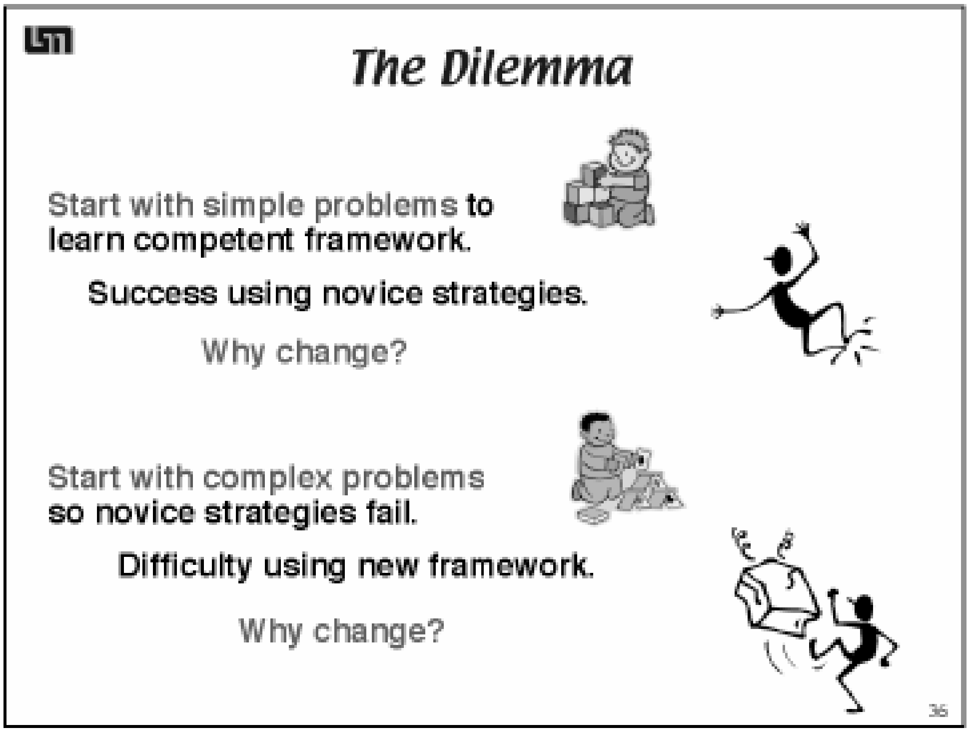
Final State

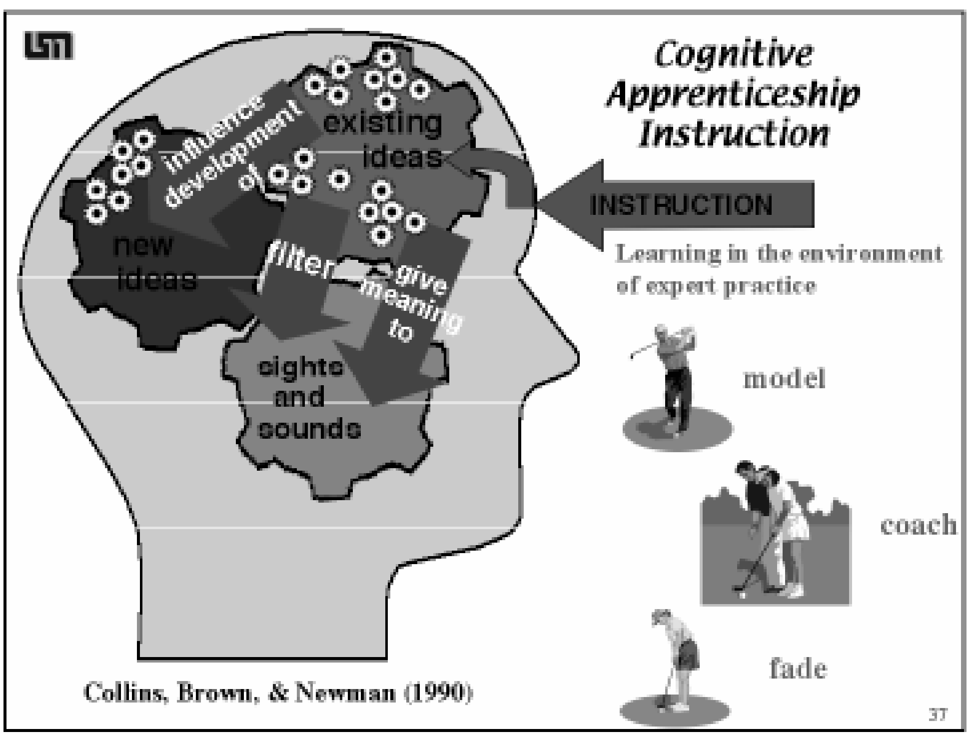


No Change!

Why do you think this experiment failed?

35


The Dilemma
Start with simple problems to learn competent framework.
Success using novice strategies.
Why change?
Start with complex problems so novice strategies fail.
Difficulty using new framework.
Why change?
36


Cognitive Apprenticeship Instruction
existing ideas
influence development of
new ideas
filter
give meaning to
sights and sounds
INSTRUCTION
Learning in the environment of expert practice
model
coach
fade
Collins, Brown, & Newman (1990)
37

Cooperative Problem Solving "Full Model"

Emphasis: Fundamental Physics Principles & Problem Solving

Problem Design and Problem-solving Framework
based on expert-novice research

Coaching based on collaborative learning research

Constraints: Lecture, 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

38

Recitation Sections

Traditional Recitation Sections Do Not Work

- Instructor chooses problems to solve for students
- Students choose problems for instructor to solve
- Instructor gives review of professor's lecture

→ Less efficient lectures

Use Recitation Section for Coaching

Students work on an appropriate task
- In small groups (peer coaching)
- Intervention by instructor (expert coaching)

Need
- Appropriate task
- Group structure
- Intervention tactics

→ Cooperative Group Problem Solving

41