Activity 4. Rationale for UMN Model

Where We Started
The Introductory Physics Courses

4 lectures/week
50 minutes
200 students

Disconnected lab
2 hours/week
16 students

No recitation sections

Not a popular course to teach or take!

Research Based Instructional Design (Engineering)

Overall Objective
Understand Physics

Specific Goal(s)

Basic Theories
Design Principles
Rules of Thumb
Constraints

Knowledge Base of Field

Failure modes
Design

Cognitive Psychology
Curriculum & Instruction
Experience
People & Management
Situation
### 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
- 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

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### 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.
What Is Problem Solving?

“Process of Moving Toward a Goal When Path is Uncertain.”
- If you know how to do it, it's 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

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
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

Solving Problems Requires

Metacognitive Skills:

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

Transformation Process

Initial State of Learner
Curriculum Instructional Framework
Barriers
Desired Final State of Learner

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

Physics test. Notes and calculations written on the page.
What is the Initial State of a Physics Learner?

Students have difficulty solving problems because they have poor mathematical skills!

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

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**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 angle 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.
Atwood Solutions
(N = 174)

<table>
<thead>
<tr>
<th>Type of Solution</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Correct or minor errors</td>
<td>29</td>
</tr>
<tr>
<td>2. Careless; many omissions; no sense of order</td>
<td>9</td>
</tr>
<tr>
<td>3. Incorrect Physics Approaches</td>
<td>52</td>
</tr>
<tr>
<td>4. Mathematics Problems</td>
<td></td>
</tr>
<tr>
<td>a. Can’t solve simultaneous equations</td>
<td>6</td>
</tr>
<tr>
<td>b. Trigonometry or algebra errors</td>
<td>3</td>
</tr>
</tbody>
</table>

Incorrect Physics Approaches: Atwood Machine

a. \[ F_{\text{unknown}} = \sum F_{\text{known}} \]
\[ T = F_{\text{net}} = f_1 + f_2 - m_2 g \sin \theta \]
\[ \sum F = 0 \]
\[ \sum F = T - f_1 - f_2 = 0 \]
\[ F_{\text{unknown}} = ma \]
\[ F = T = ma = m_2 g \sin \theta \]

b. Incomplete, can’t tell 11%
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”.

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 theEducative Process


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


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**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."
**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

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**Initial State of the Learner**

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

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**Typical Student Test**

[Image of a student's test with various mistakes and solutions]
**Instructional Design Principle**

Transformation Process

- Initial State of Learner
- Paths
- Curriculum Instructional Framework
- Barriers
- Desired Final State of Learner
- Instructor

F. Reif (1986)
*Phys. Today* 39

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**Typical Student Test**

**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).
From Novice to Expert Problem Solver

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

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.
Experiment 1:
Show (model) how to use “competent” problem solving framework in lecture

Why do you think this experiment failed?

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?
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?

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.
**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.

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**Experiment 2:**

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

Initial State

Final State

Why do you think this experiment failed?
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?

Cognitive Apprenticeship Instruction

Learning in the environment of expert practice
- model
- coach
- fade

**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

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**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**