WHY SOLVE PROBLEMS? - INTERVIEWING COLLEGE FACULTY ABOUT THE LEARNING AND TEACHING OF PROBLEM SOLVING*

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Rationale for Study

Wide agreement:
• Traditionally physics is taught by solving problems
• Many students cannot solve traditional problems
• Many of those who can do not understand the underlying physics concepts [McDermott, 1984, Halloun & Hestenes, 1985]

Research based curricular efforts:
• Directly building students’ conceptual knowledge
  [Mazur et al - Peer Instruction, McDermott et al - Tutorials]
• Developing student problem solving skills
  [Heller et al - CGPS, Mestre et al - MOP, Reif et al - PALs, Van Heuveln - OCS]

Instructors’ practice: Reflect some aspects of research based curricula. Yet, seldom are they fully implemented
Reflects tension between those who shape the learning environment

Curriculum developers
 Learning vision
 Control artifacts
 Complain about instruction

Instructors
 Teaching realities
 Control schedules, roles
 Complain about curriculum
Instructor independent curricula

No instructor or instructor proof
Instructor Dependent Curricula

Cooperation ➔ Communication ➔

Focus of study: Faculty beliefs about learning and teaching of problem solving

1\textsuperscript{st} stage: Elicit parameters for instructional choices
⇒ Interview sample (Minnesota sample)

2\textsuperscript{nd} stage: Map parameters into the community
⇒ Directed survey (National sample)

Goal: Use results to
• Clarify language and promote instructors’ discussion
• Match curricular design to instructors concerns
• Determine possible professional development
Research Method

Caution!! Schoenfeld: Different instructor beliefs are activated by different events in actual practice.

⇒ Beware of general setting!
Capture instructors’ rationale for their choices by inducing reflection on practice through comparisons between variety of curricular artifacts

Interview artifacts:
- 5 problems (same physics situation)
- 3 instructors’ solutions (to 1st problem)
- 5 students’ solutions (to 1st problem)

“Universal”: Range of common instructional practices
Range of problem solving processes (research based)
Problems

Verbal
You are **whirling a stone tied to the end of a string** around in a **vertical circle** having a **radius** of 65 cm. You wish to whirl the stone fast enough so that when it is **released at the point where the stone is moving directly upward**, it will **rise to a maximum height of 23 meters above the lowest point in the circle**. In order to do this, **what force will you have to exert on the string when the stone passes through its lowest point** one-quarter turn before release? Assume that by the time that you have gotten the stone going and it makes its final turn around the circle, you are holding the **end of the string at a fixed position**. Assume also that air resistance can be neglected. **The stone weighs** 18 N.

Schematic + Stepped
A 1.8 kg mass is attached to a frictionless pivot point...

\[ \text{String breaks here} \]

A) What velocity, \( v_1 \), must the stone have when released in order to rise to 23 meters above the lowest point in the circle?

B) ...

C) ...

+ Multiple-choice, “Real-world” context, & Qualitative
Instructor Solutions

Bare bones

- The tension does no work.
- Conservation of energy between point A and B:
  \[ Mv_A^2/2 = mgh \]
  \[ V_A^2 = 2gh \]
- At point A, Newton’s 2nd Law gives us:
  \[ T - w = ma \]
  \[ T - w = mv_A^2/R \]
  \[ T = 18 \text{ N} + 2 \cdot 18 \text{ N} \cdot 23 \text{ m} / 6.5 \text{ m} = 1292 \text{ N} \]

Decision making process

**Approach:**
I need to find \( F_m \), force exerted by me.

A)...

B) I can relate \( v_b \) to \( v_t \) using either

i) energy, ii) Dynamics and kinematics

ii) Messy since forces/accelerations change through the circular path.

i) I can apply work-energy theorem for stone. Path has 2 parts: ...

**Execution:**

A) Relate \( T_b \) to \( v_b \):

\[ \sum F_R = ma_R \]

... Large compared to weight

Check limits: \( T_b \) ↑ as \( R \) ↓
**Student Solutions**

**Reasoned, wrong**

\[ \begin{align*}
    v_f &= 0 \\
    v_t &= 0 \\
    v_f &= ? \\
    w &= ? \\
    x &= ? \\
    m_1 &= 15 kg \\
    h &= 2.3 m \\
    R &= 0.65 m
\end{align*} \]

Find velocity to reach height \( h \) (Free Fall)

\[ \begin{align*}
    v_f^2 - v_0^2 &= 2a (y - y_0) \\
    v_f^2 &= 2a (y - y_0) \\
    v_f &= \sqrt{2ay} \\
    v_f &= \sqrt{2 \times 9.8 \times 2.3} \\
    v_f &= 20.9 m/s
\end{align*} \]

It can't be true \( v_f = v_0 \) but I don't know how to relate them. If \( v_f = v_0 \), then:

Find force

\[ \begin{align*}
    F &= m \cdot a \\
    T - mg &= m \cdot \frac{v_f^2}{R} \\
    T &= mg + m \cdot \frac{v_f^2}{R} = 18 N + \frac{18N}{0.65 m} (20.9 m/s)^2 \\
    \text{Force exerted by me} &= 1286 N
\end{align*} \]

Looks large, but stone needs to go up for

---

**Short, correct?**

\[ \begin{align*}
    v_f^2 &= 2gh \\
    F - mg &= \frac{m \cdot 2gh}{R} \\
    F &= 18 + \frac{2 \cdot 18 \cdot 23}{0.65} = 1292 N
\end{align*} \]

+ 3 others: all 5 are based on actual student solutions from final exam at the University of Minnesota
“Research” → Interview Questions

Goal: To find out instructors’ teaching models

Si What students bring to the class?
Si What instructors do to promote learning?
Sf What students do to learn?
Sf What students take from class?

All in respect to problem solving

Constraints on teaching model

[Reif, 1994]

Interaction between student and instructor that shapes the learning environment
Structure of the Interview

Homework problem. 1½ hours, four parts.

1st) **Instructor solutions:** Focus on instructor, correct solution
2nd) **Student solutions:** What students give to instructors
3rd) **Problems:** Expand to different problems

Story line anchored in instructor practice.
In all 3 parts:
- How and why artifact is used?
  - Abstract
  - Concrete

Reflect on students’ problem solving based on artifacts each problem solving feature on separate index card

4th) Instructor sorts index cards into categories of their choice
Questions regarding these categories
Administration of Interview

Physics faculty in Minnesota, taught introductory calculus-based physics course in the last 5 years, could be visited and interviewed in a single day, randomly selected (107 possible).

Final sample: 31 faculty members (From 36 contacted 5 declined to be interviewed). Roughly divided between:
1) Community College
2) Private College
3) Research University
4) State College

Many did not want to quit interview after 1½ hours

Videotaped
Transcribed (~30 pages of text / interview)
Developing the Analysis:

At minimum the analysis should:
- Find differences between instructors with different practices
- Elicit aspects of problem solving from Instructors familiar or not familiar with PS research

Focus: Two instructors we know [Foster, 2000] have different practices. Both:
- Active research physicists
- Won Teaching Awards
- Taught the same intro course, same departmental structure (CGPS)

<table>
<thead>
<tr>
<th>EPS - Explicit Problem Solving</th>
<th>TRD - TRaditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses Explicit Problem Solving Strategy</td>
<td>No consistent approach to Problem Solving</td>
</tr>
<tr>
<td>Familiar with problem solving research</td>
<td>Not familiar with problem solving research</td>
</tr>
</tbody>
</table>

Analyze remainder of the interviews
Analysis Procedure

For Each Instructor*:
• Break the interview transcript into units
• Categorize the units
• Reconstruct
  1. Teaching Models
  2. Awareness of aspects of problem solving

Example from first part of interview (Instructor Solution II).
Q: “Take a look at each of these instructor solutions and describe how they are similar or different to your solutions.”

TRD: “I worry about too much detail in a solution. I think it turns them [students] off in some ways. They kind of want the quick and dirty deal here.”

*[Miles, M. & Huberman, A. (1994) *Qualitative Data Analysis*.]
Unit: Smallest piece of text describing an action or internal state of a student or instructor.

“I worry about too detailed of a solution. I think it turns them [students] off in some ways. They kind of want the quick and dirty deal here.” TRD interview

Break to units, and Categorize:
1. I don’t like to give out solutions with too much detail
2. Students don’t like solutions with too much detail
3. Students like quick and dirty solutions

<table>
<thead>
<tr>
<th></th>
<th>External</th>
<th>Internal</th>
<th>Unclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Focus on groups of units to reconstruct model: from one set of thoughts based on time sequence and internal references
## 1. Reconstructing Teaching Models

### TRD Instructor

<table>
<thead>
<tr>
<th>Model</th>
<th>Initial State of Student</th>
<th>Instructor Action</th>
<th>Student Action</th>
<th>Final State of Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>Provide structured solutions</td>
<td>Understand the structure of instructor solutions</td>
<td>Use this understanding when solving problems</td>
<td></td>
</tr>
<tr>
<td>Model 2</td>
<td>Don’t like detailed solutions</td>
<td>Provide solutions without too much detail</td>
<td>Perceive problem as easy</td>
<td></td>
</tr>
<tr>
<td>Model 3</td>
<td>Higher-level students can understand solution</td>
<td>I gear solutions to higher-level students</td>
<td>Higher-level students can use this when solving problems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower-level students cannot understand solution</td>
<td>I don’t gear solutions to lower-level students</td>
<td>Lower-level students get left behind</td>
<td></td>
</tr>
<tr>
<td>Model 1</td>
<td>Initial State of Student</td>
<td>Instructor Action</td>
<td>Student Action</td>
<td>Final State of Student</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------</td>
<td>-------------------</td>
<td>----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td></td>
<td>Students are not good at properly structuring their solutions</td>
<td>Provide structured solutions</td>
<td>Understand the structure of instructor solutions</td>
<td>Use this understanding when solving problems</td>
</tr>
</tbody>
</table>

**EPS has 1 model, TRD has 3, possibly incomplete models**

**Is Model 1, “structured solutions” the same for both?**

- **TRD** - Fewer external actions, sometimes vague: “Draw pictures”, “Professional physicist strategy for problem solving”
- **EPS** - More external actions, specific and detailed: “Diagrams that include v and a”, “Explicitly state choices and decisions”
2. Reconstructing Aspects of Problem Solving

Procedure:
• Categorize the units from different parts of the interview into the aspects of PS.

Results:
• Each instructor mentioned similar aspects of problem solving.
• There were differences in emphasis within each aspect. For example, under General Decision Making
  → Both mentioned evaluating progress and results
  → TRD emphasized exploration (trial and revision)
  → EPS emphasized weighing choices in making decisions
Is this type of analysis meaningful?

Our analysis allows us to find differences between the two instructors corresponding with their different practices.

**BELIEFS**

<table>
<thead>
<tr>
<th>Reconstruction:</th>
<th>TRD</th>
<th>EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching model</td>
<td>3, Competing, more general, not “complete” models</td>
<td>1 Specific, complete model</td>
</tr>
<tr>
<td>Problem solving aspects</td>
<td>mentioned similar aspects of problem solving, but with differences in attributes and in external manifestations</td>
<td></td>
</tr>
</tbody>
</table>

**PRACTICE**

<table>
<thead>
<tr>
<th>Observer + Self-Reporting:</th>
<th>TRD</th>
<th>EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No consistent approach (to problem solving)</td>
<td>Consistent use of problem solving strategy</td>
<td></td>
</tr>
</tbody>
</table>

Competing models result in inconsistent actions, TRD:

→ “I want to see their reasoning”

→ “I am not particularly in favor of knocking people off ... if they see an answer and go right to it”
Is this type of analysis fruitful?

If we can get similar information from the other 29 interviews we will be able to:

• **Determine possible professional development**
  • No need to develop awareness of aspects of problem solving
  • Need to develop awareness of competing teaching models

• **Match curricular design to instructors concerns**
  • Need to address student likes/dislikes

• **Clarify language used by instructors**
  • “Structured Solutions”

Refine our analysis (suggestions invited - Idit@physics.umn.edu
http://www.physics.umn.edu/groups/physed/)