WHY SOLVE PROBLEMS? – INTERVIEWING COLLEGE FACULTY ABOUT

THE LEARNING AND TEACHING OF PROBLEM SOLVING*

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Rationale for Study

Wide agreement:

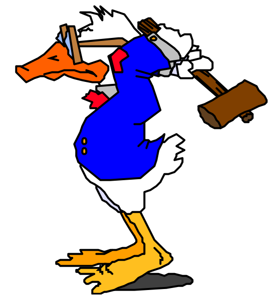
- Traditionally physics is taught by solving problems
- Many students cannot solve traditional problems
- Many of those who can do not understand the underlying physics concepts [McDermott, 1984, Halloun & Hestenes, 1985]

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 Heuvlen - 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

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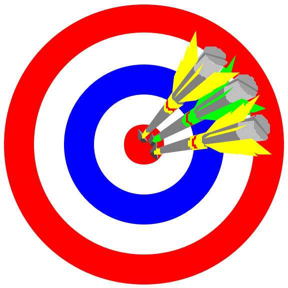
Instructor independent curricula

No instructor or instructor proof

Instructor Dependent Curricula



Cooperation Þ Communication Þ

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

1st stage: Elicit parameters for instructional choices

⇒ Interview sample (Minnesota sample)

2nd 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)

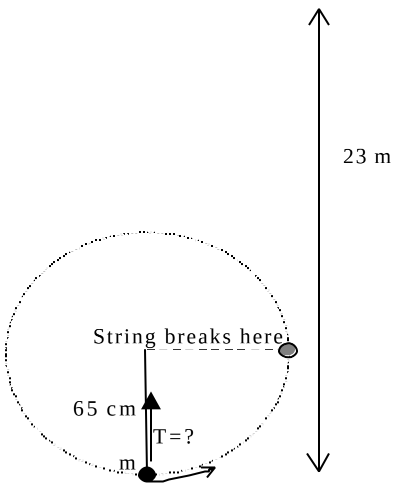
Problems

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…



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?

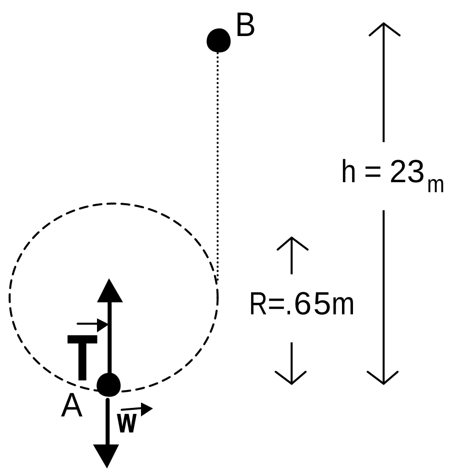
B) ...

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:

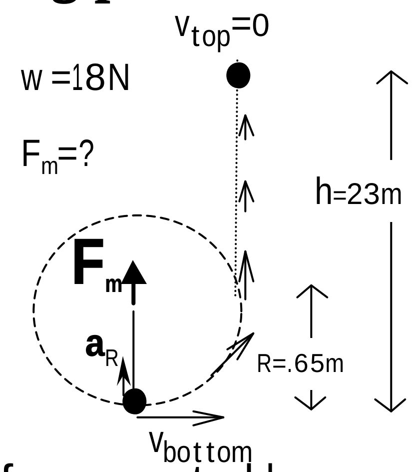
T- w = ma

$T - w = mv_A^2/R$

$T= 18_N + 2\cdot 18_N \cdot 23_m / .65_m =$ $\boxed{1292N}$

+ Detailed presentation

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 theorm for stone. Path has 2 parts: ...

Execution:

A) Relate T_b to v_b: $\sum F_R = ma_R$

...

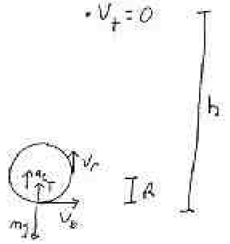
$\boxed{1292N}$

Large compared to weight

Check limits: $T_b \uparrow$ as R $\downarrow$

Student Solutions

Reasoned, wrong



$V_t = 0$
$V_r = ?$
$V_b = ?$
$T = ?$
$mg = 18N$
$h = 23m$
$R = 0.65m$

Find velocity to reach height (Free Fall)

$$V^2 - V_0^2 = 2a(y - y_0)$$
$$\cancel{0 - V_r^2 = 2(-g)(h)}$$
$$0 - V_r^2 = 2(-g)(h - R)$$
$$V_r = \sqrt{2g(h-R)}$$
$$= \sqrt{2 \cdot 9.8\,m/s^2 \cdot (23 - 0.65)\,m} \qquad \sqrt{m/s^2 \cdot m} = m/s$$
$$= 20.9\,m/s$$

It can't be that $V_r = V_b$ but I don't know how to relate them. If $V_r = V_b$, then:

Uses $V_{release}$ instead of V_{bottom}

Find Force

$$\Sigma \vec{F} = m\vec{a}$$
$$T - mg = ma_c$$
$$N + \frac{N}{m/s^2} \cdot \frac{m^2/s^2}{m} = N$$
$$T = mg + \frac{mv_r^2}{R} = 18N + \frac{\frac{18N}{9.8\,m/s^2}(20.9\,m/s)^2}{0.65m}$$

Force exerted by me $= 1256N$

Looks large, but stone needs to go up far

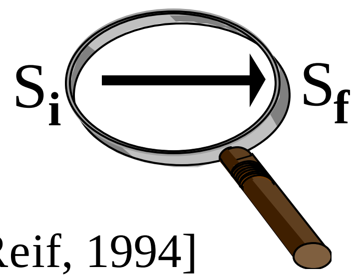
Short, correct?

$$V^2 = 2gh$$
$$F - mg = \frac{m\,2gh}{R}$$
$$F = 18 + \frac{2 \cdot 18 \cdot 23}{.65} = 1292\,N$$

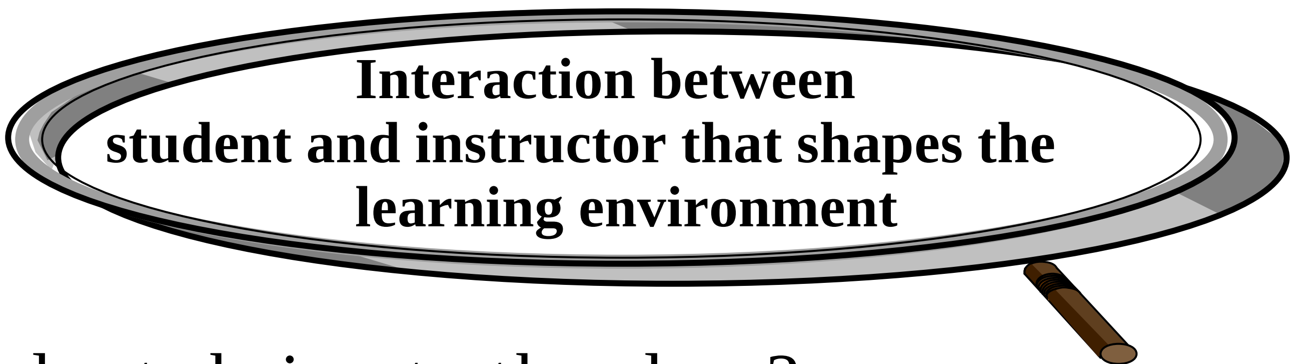
+ 3 others: all 5 are based on actual student solutions from final exam at the University of Minnesota

"Research" → Interview Questions

Goal: To find out instructors' teaching models



[Reif, 1994]



S_i What students bring to the class?

$\longrightarrow$ What instructors do to promote learning?
What students do to learn?

S_f What students take from class?

All in respect to problem solving

Constraints on teaching model

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)**

EPS - **E**xplicit **P**roblem **S**olving	**TRD** - **TR**a**D**itional
Uses Explicit Problem Solving Strategy	No consistent approach to Problem Solving
Familiar with problem solving research	Not familiar with problem solving research

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

<u>Break to units, and Categorize :</u>

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**

	External	**Internal**	**Unclear**
Student			
Instructor			

<u>Focus on groups of units to reconstruct model</u>: from one set of thoughts based on time sequence and internal references

1. Reconstructing Teaching Models

TRD Instructor

All Models from part 1: Instructor Solutions	Initial State of Student	Instructor Action	Student Action	Final State of Student
Model 1		Provide structured solutions	Understand the structure of instructor solutions	Use this understanding when solving problems
Model 2	Don't like detailed solutions	Provide solutions without too much detail	Perceive problem as easy	
Model 3	Higher-level students can understand solution	I gear solutions to higher-level students		Higher-level students can use this when solving problems
	Lower-level students cannot understand solution	I don't gear solutions to lower-level students		Lower-level students get left behind

EPS Instructor

All Models from part 1: Instructor Solutions	Initial State of Student	Instructor Action	Student Action	Final State of Student
Model 1	Students are not good at properly structuring their solutions	Provide structured solutions	Understand the structure of instructor solutions	Use this understanding when solving problems

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

Reconstruction:	**TRD**	**EPS**
Teaching model	3, Competing, more general, not "complete" models	1 Specific, complete model
Problem solving aspects	mentioned similar aspects of problem solving, but with differences in attributes and in external manifestations	

PRACTICE

Observer + Self-Reporting:	No consistent approach (to problem solving)	Consistent use of problem solving strategy

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/)