Faculty Conceptions About the Teaching and Learning of Problem Solving*

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

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Recent Graduates
Dr. Tom Foster (2000), Assistant Professor, SIUE
Dr. Laura McCullough (2000), Assistant Professor, UW-Stout

Some Current Projects:

- Curriculum development at the introductory level: Problem Solving Focus (Cooperative Group Problem Solving, Problem Solving Laboratories, Problem Solving Framework w/ Context Rich Problems)
- Research into stability of curricular changes and faculty adoption of innovative curricula (Faculty Conceptions)
- Student-Centered Curriculum Development (CPU - high school and college; CIPS – middle school)

Overview

1. Why study faculty conceptions?
2. Research Methods

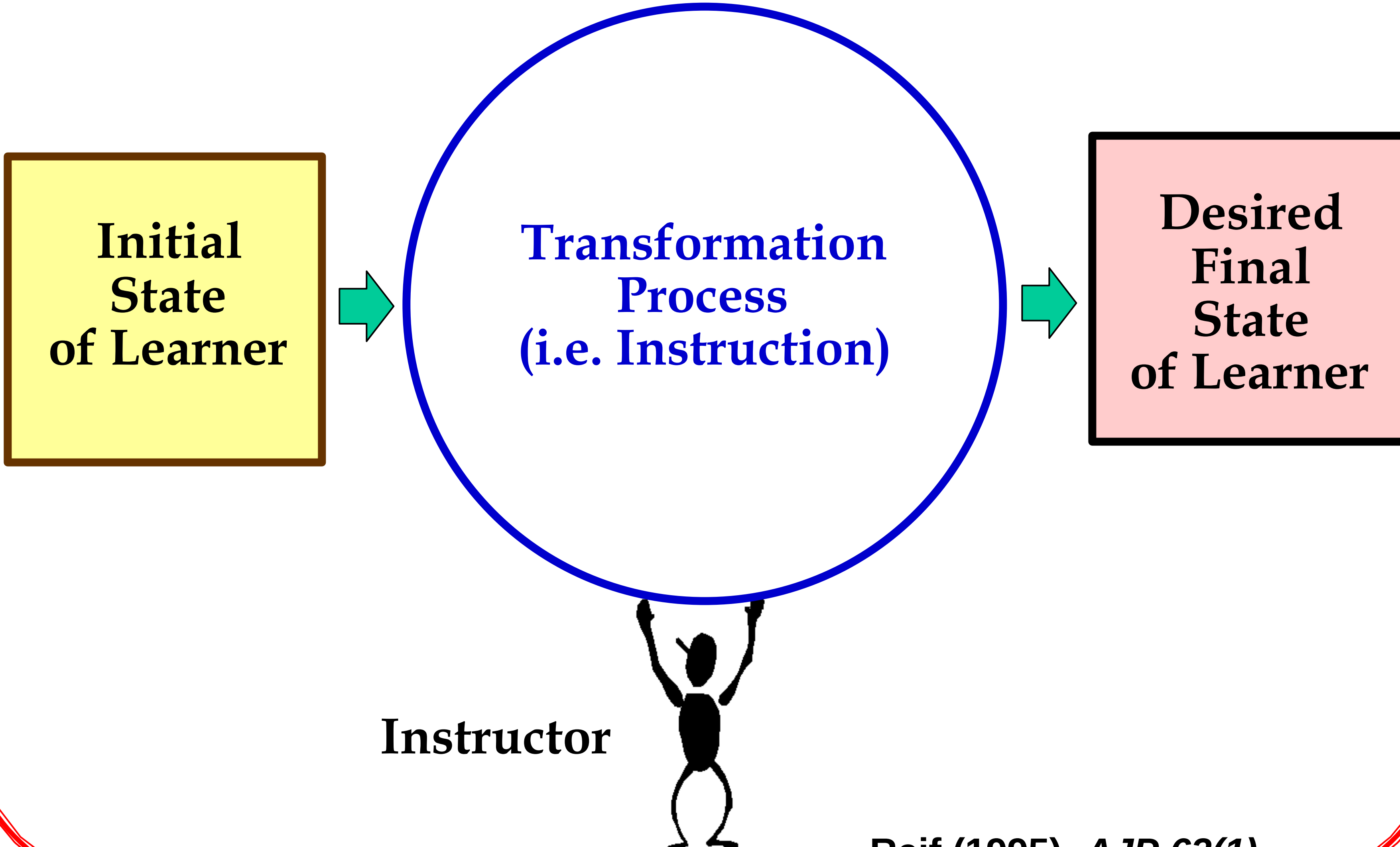
   - The Interview Tool

   - Selecting Faculty for Interviews

   - Analyzing Interview Data

3. What can we do with the results?

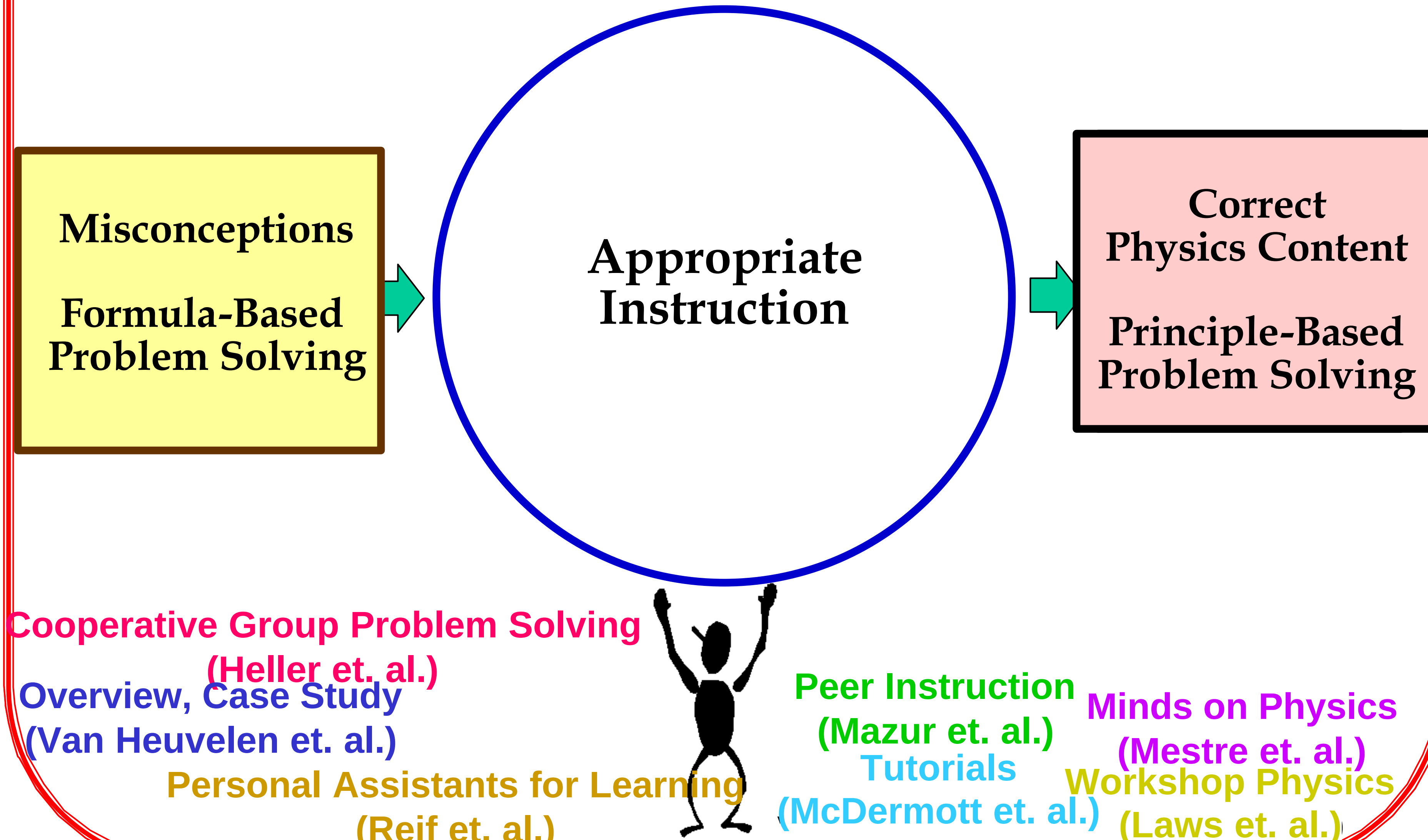
The Instructional Problem



Reif (1995), *AJP 63(1)*

What do we know from

Physics Education Research?



What is the difficulty with these research-based curricular materials? Why aren't they widely used?

- **Our theory: The available curricular materials do not fit well with faculty conceptions (i.e. beliefs, values, knowledge, etc.) of teaching and learning**

- **If this is the case then we have two choices:**

1. **Change the curricular materials**

   (curricular materials built on faculty conceptions are more likely to be used and more likely to be used appropriately)

2. **Change the faculty conceptions**

   We know from students:

   - **Changing conceptions is hard.**
   - **In order to change conceptions it is first necessary to determine what the current conceptions are.**

Goal of this Study

- **Begin the process of building a model of faculty conceptions (beliefs and values) about the teaching and learning of problem solving in introductory calculus-based physics.**
    - **Can (how can) faculty conceptions be measured?**
    - **Can (how can) a model be constructed to describe these conceptions?**
        - **What are the important parts of this model?**
        - **How are these parts related?**

- **The focus of this study is on problem solving because the Physics Education Research Group at UMN is interested in problem solving.**

The Interview Tool

To investigate faculty conceptions, we developed a 1½ - 2 hour interview based on instructional "artifacts":

1st) 3 Instructor solutions: varied in the details of their explanation, physics approach, and presentation structure

2nd) 5 Student solutions: based on actual final examination solutions at the University of Minnesota to represent features of student practice

3rd) 4 Problem types: represent a range of the types of problems used in introductory physics courses

All artifacts were based on one problem -- instructors were given the problem and asked to solve it on their own before the interview.

Example - Part 1, Instructor solution

Q1: In what situations [during lecture, after test...] are students provided with examples of solved problems in your class. How does this work?

Q2: How would you like your students to use the solved examples you give them in these different situations? Why?

Abstract/General

Q3: Scan through each of these instructor solutions. Please describe how these solutions are similar or different to your solutions. Please explain your reasons for writing solutions the way you do.

Concrete/Specific Artifacts

Q4: Looking at the instructor solutions, what aspects/components that you consider important in problem solving are represented in these instructor solutions, and what aspects are not represented?

Conceptions of Problem Solving

Selecting Faculty for Interviews

Physics faculty in Minnesota (~107 meet selection criteria):

- **taught introductory calculus-based physics course in the last 5 years**
- **could be visited and interviewed in a single day**

Sample Randomly Selected:

30 faculty members

(From 35 contacted, 5 declined to be interviewed)

Roughly evenly divided among:

1) Community College (CC) N = 7
2) Private College (PC) N = 9
3) Research University (RU) N = 6
4) State University (SU) N=8

Interviews were videotaped and the audio portion transcribed:

~ 30 pages of text/interview

Data Analysis

Phase I : 1. Determine if the conceptions of 6 UMN faculty are coherent enough to allow a model to be developed.

2. If so, develop an initial model of faculty conceptions based on these 6 faculty.

(My Thesis!)

Phase II: Refine and expand the initial model based on remaining 24 faculty from different institutions.

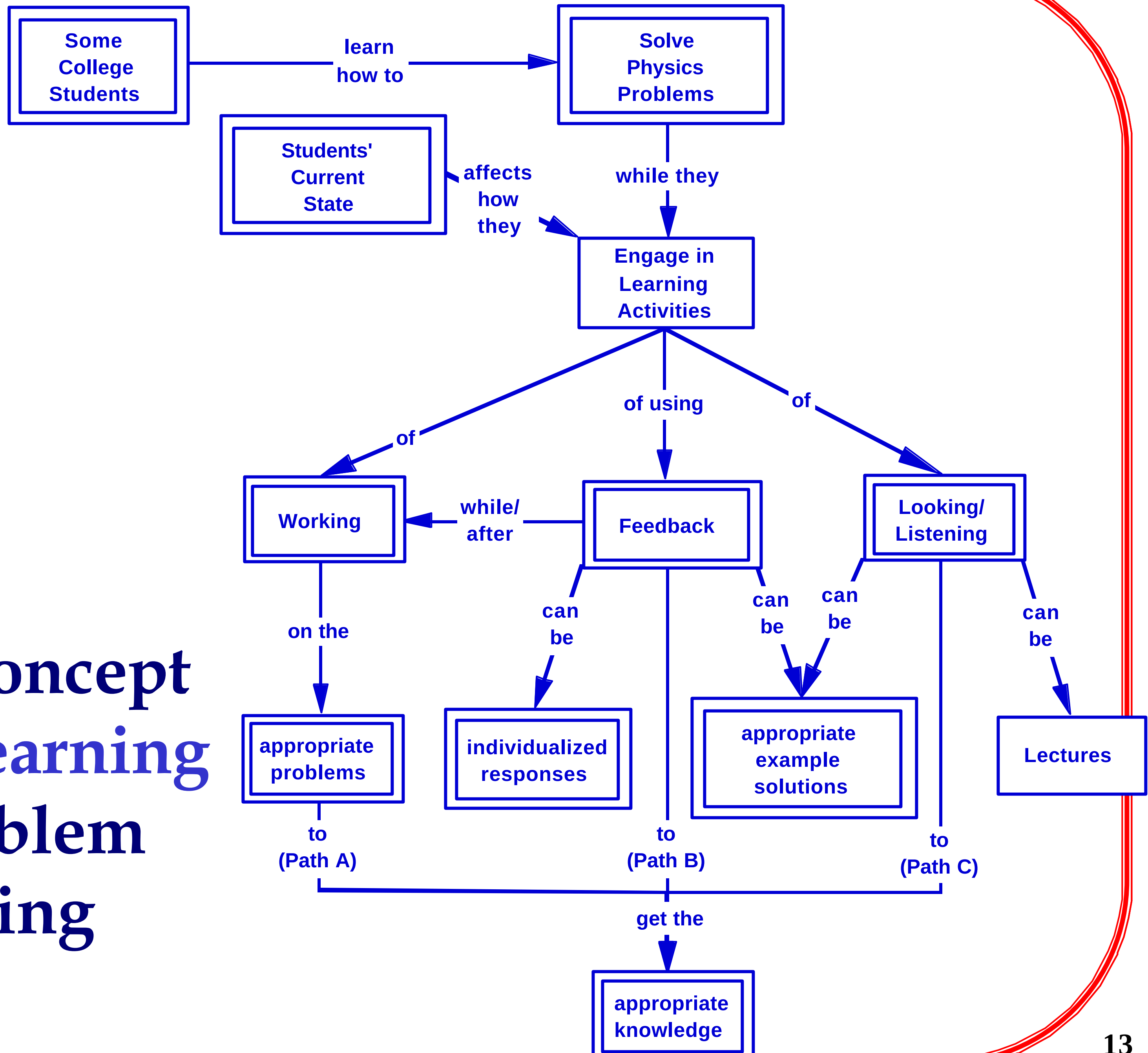
(Vince Kuo's Thesis)

Phase III: Determine the distribution of conceptions among faculty using a larger national sample.

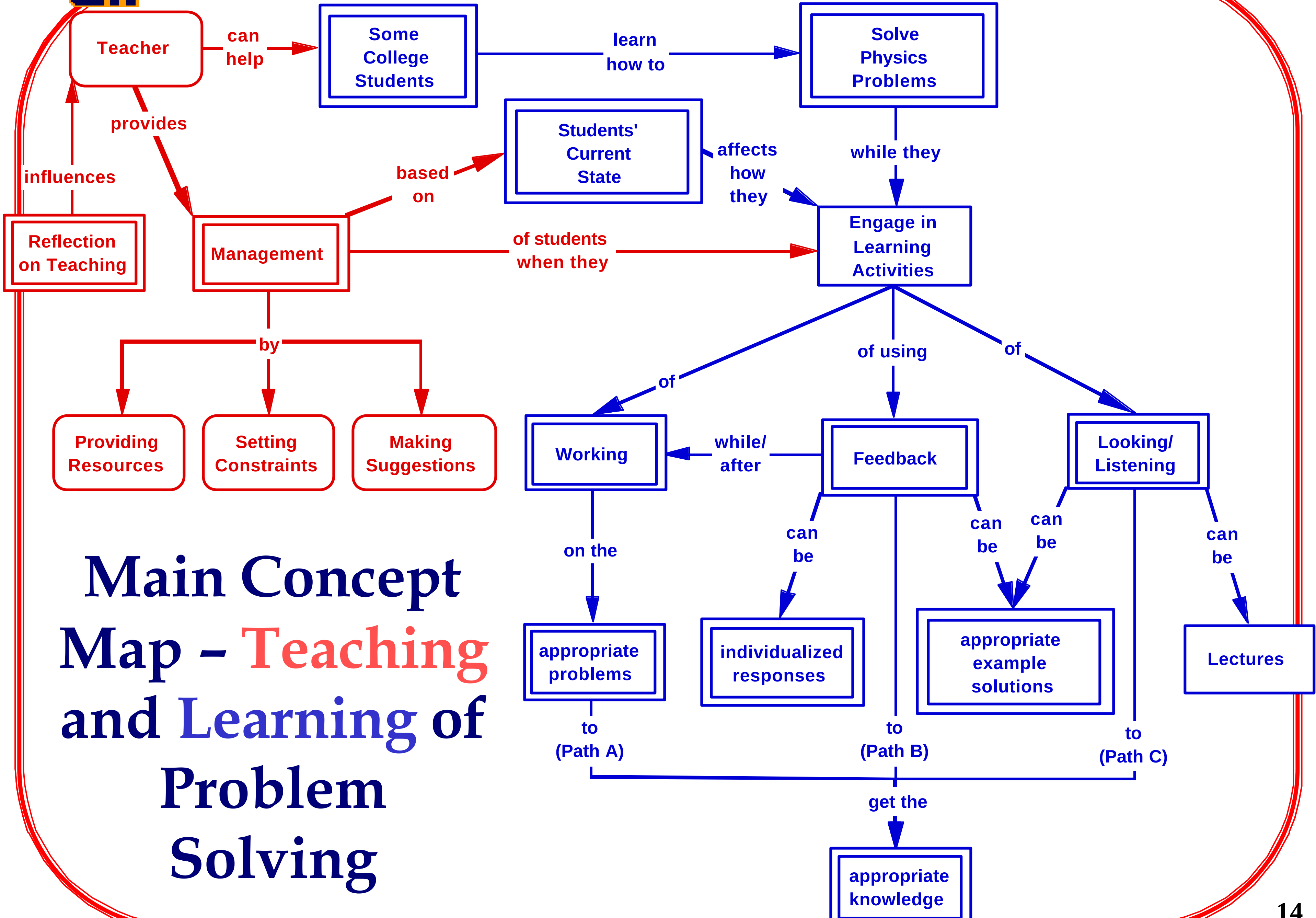
Phase I: Final Product

Final product is a concept map that describes an initial, testable model of how faculty think about the teaching and learning of problem solving.

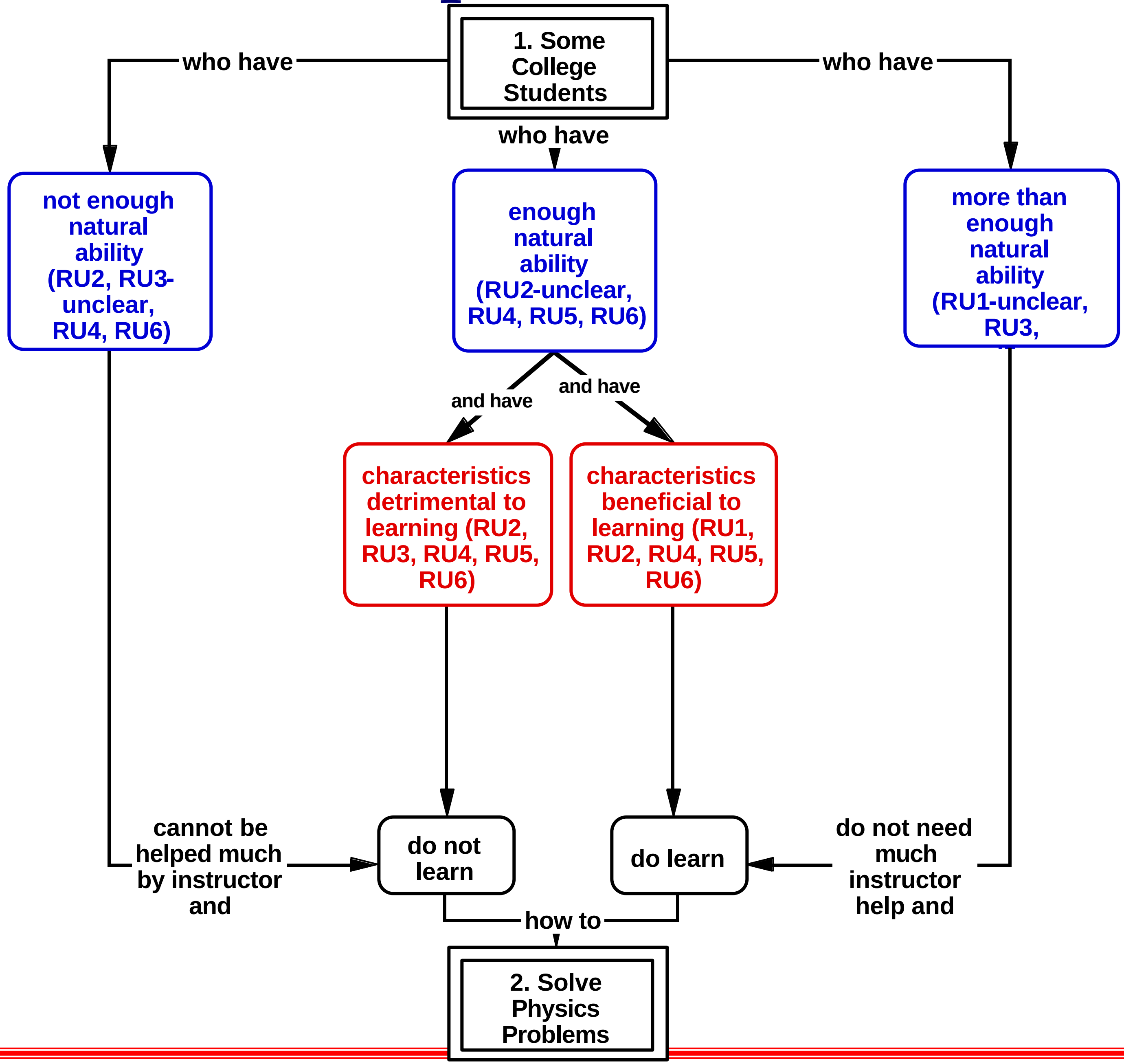
Main Concept Map –Learning of Problem Solving



Main Concept Map – Teaching and Learning of Problem Solving



Feature Maps Contain Details:



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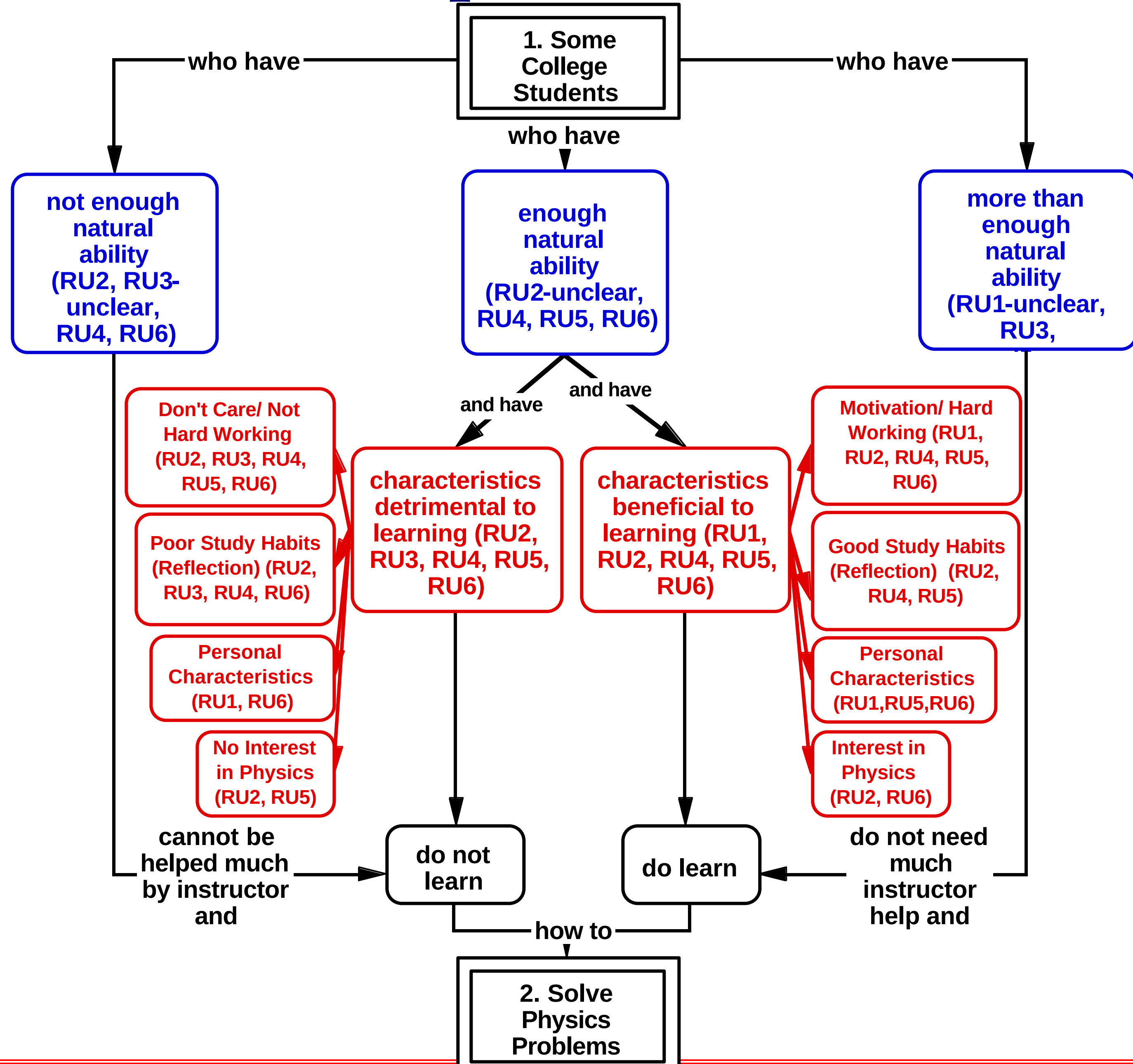

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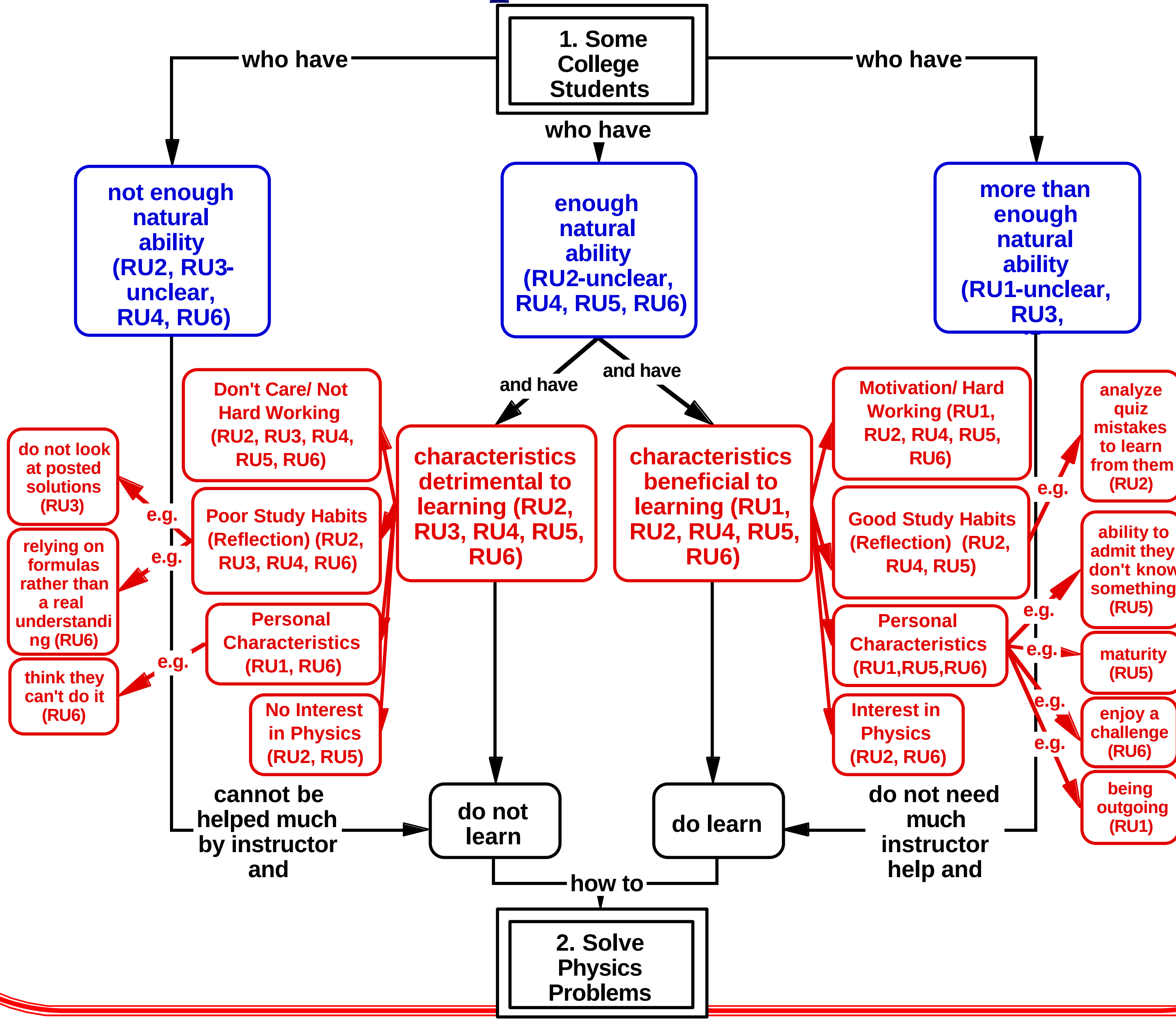

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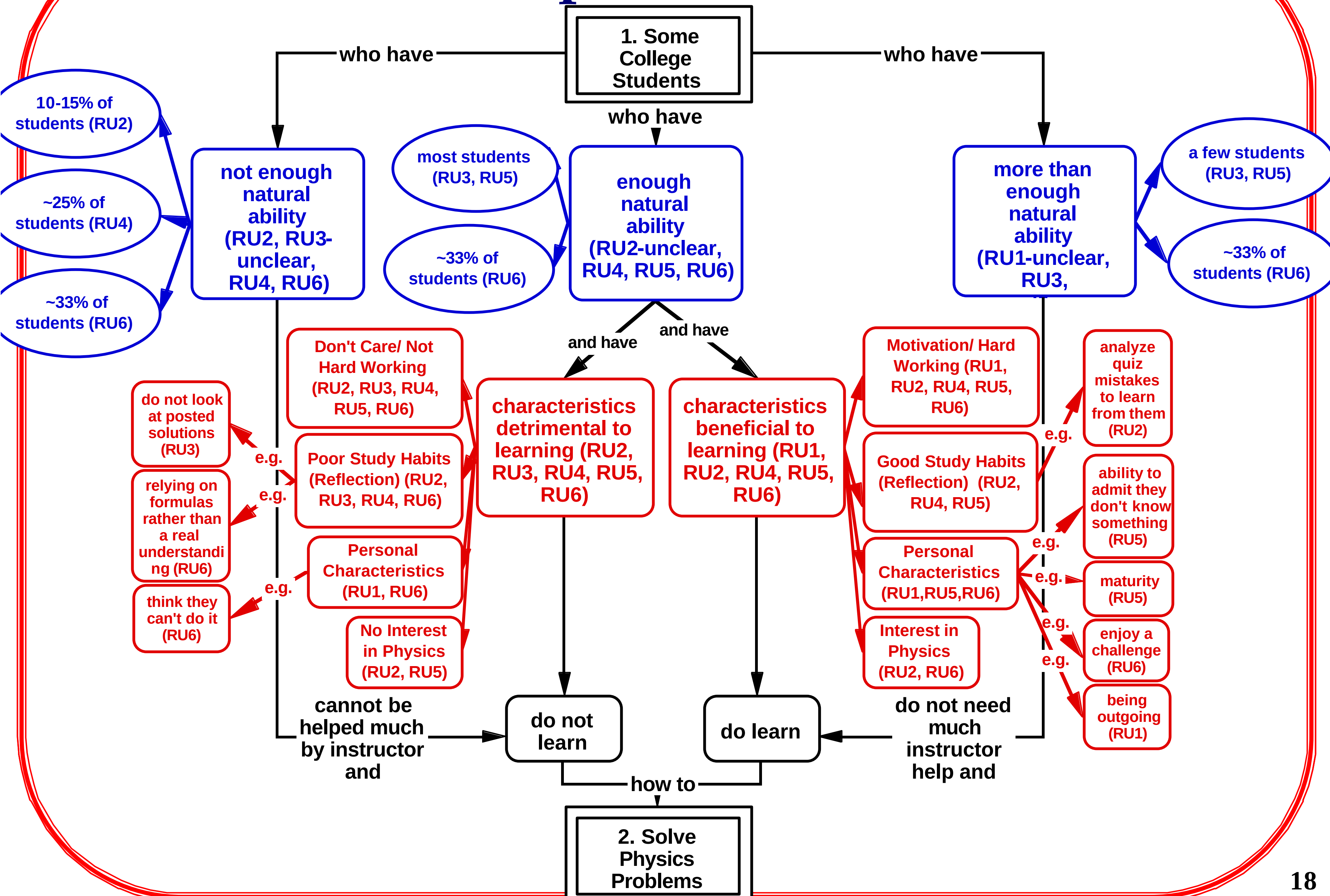

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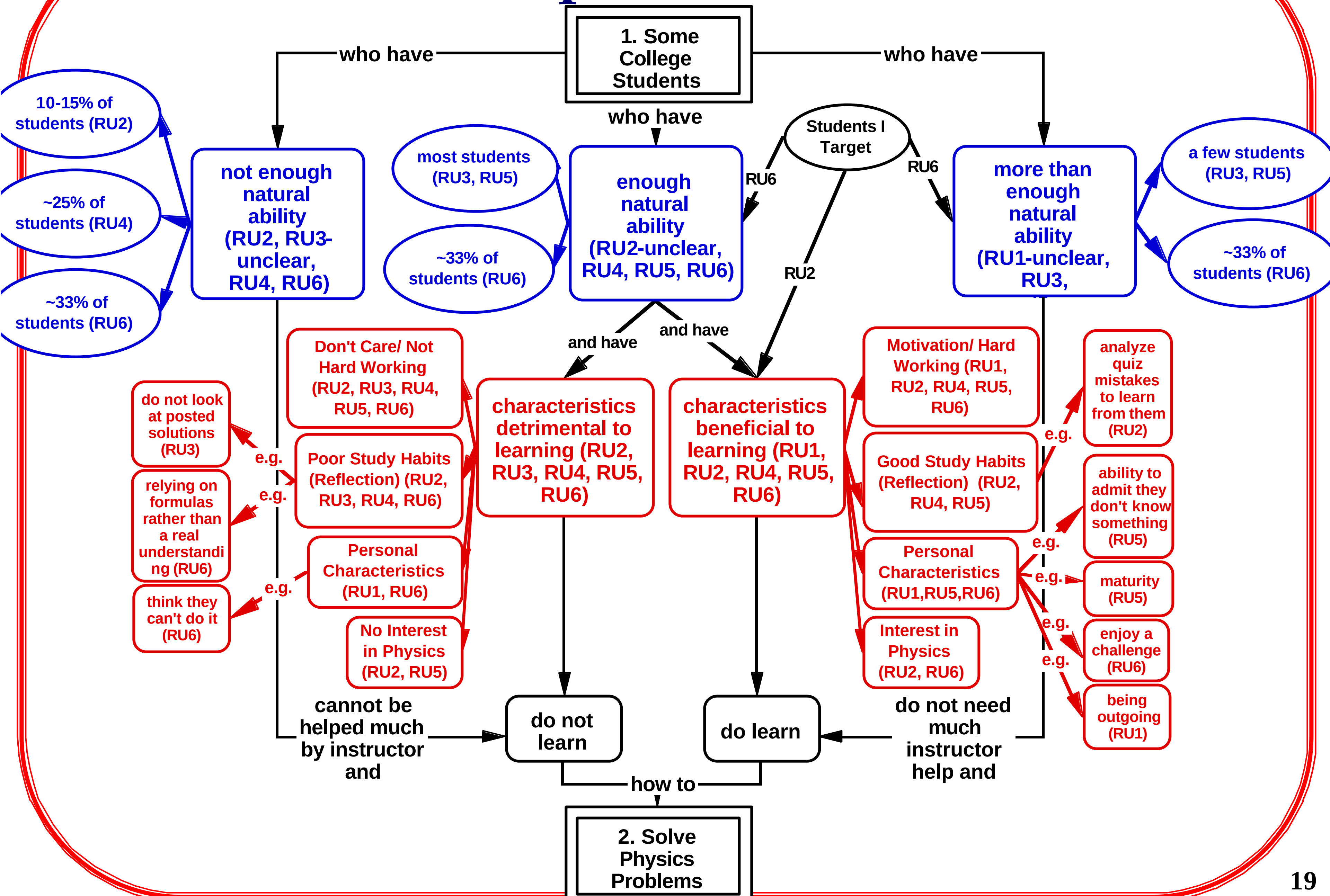
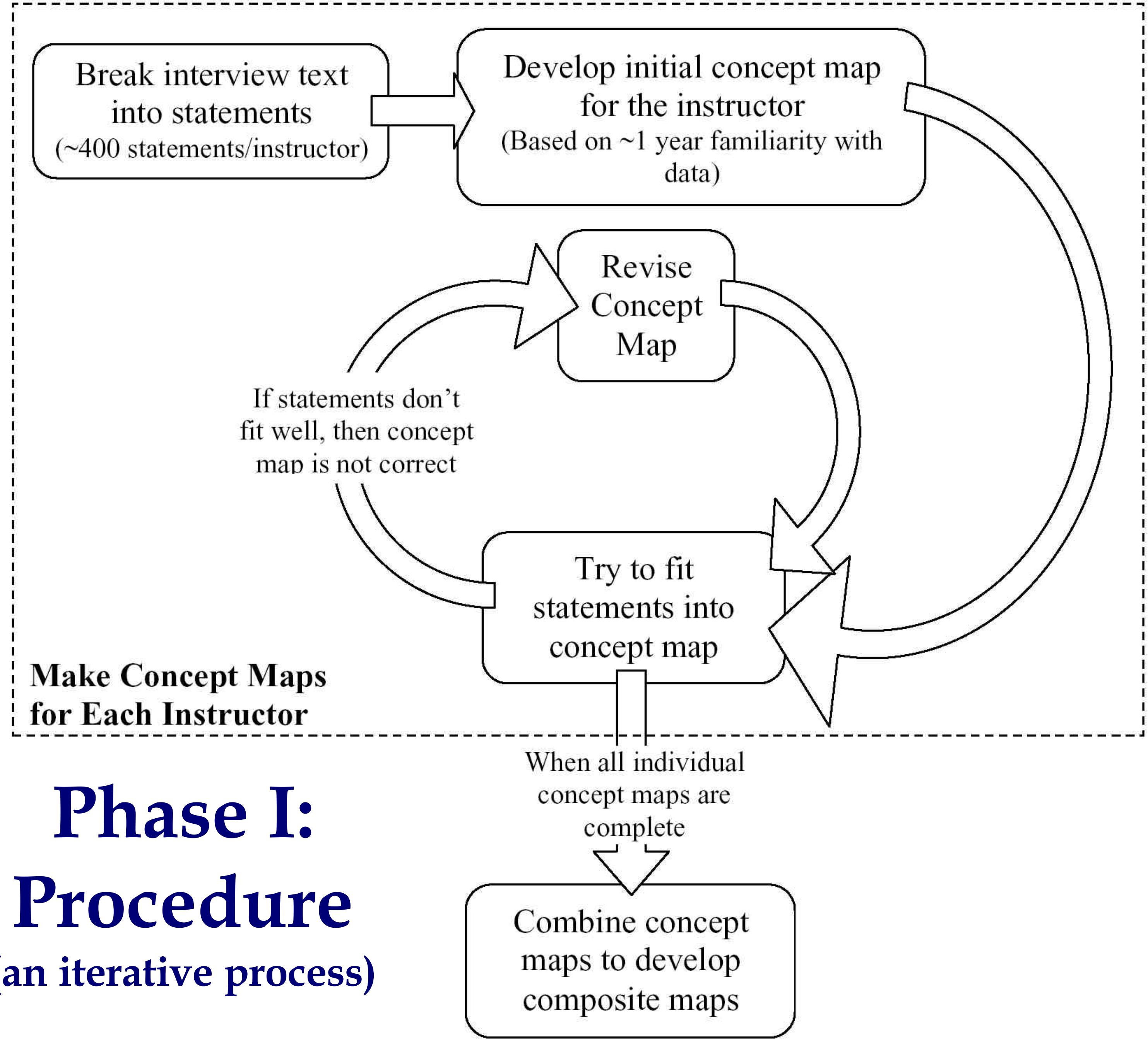




Phase I: Procedure

(an iterative process)

Why Concept Maps?

Video- & audiotapes of interviews (~9 hrs)

Interview transcripts (~180 pages)

Statements (~2400)

Concept Maps (15 x 6 = 90)

Combined Concept Map (15)

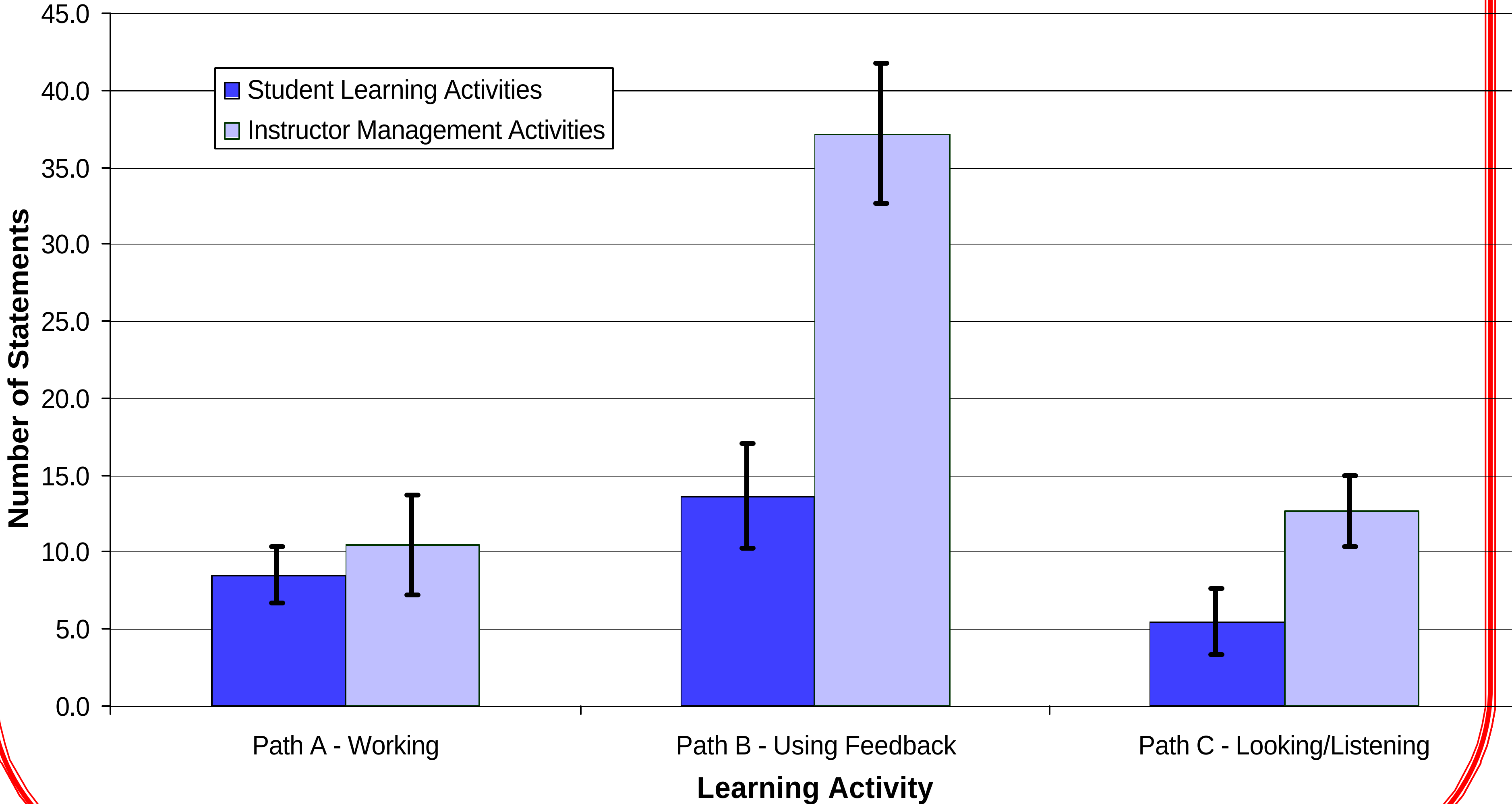
Concept Maps allow for:

- **the reduction of complex data into visual representations**
- **explicit connections to be made between ideas that can then be tested**

What Can We Do With this Model of Faculty Conceptions?

- **Explore faculty conceptions about how students learn and how faculty can help students learn.**

What do Faculty Talk About?



Summary of Management Activities

<table>
<tr><th></th><th>Setting Constraints</th><th>Making Suggestions</th><th>Providing Resources</th></tr>
<tr><td rowspan="3">Working (Path A)</td><td>On problems that students work (6 of 6)</td><td></td><td rowspan="3">Of appropriate problems (6 of 6)</td></tr>
<tr><td>On situations in which students work problems (3 of 6)</td><td></td></tr>
<tr><td></td><td>That students work on problems (3 of 6)</td></tr>
<tr><td rowspan="4">Using Feedback (Path B)</td><td rowspan="2">That students work on problems by collecting solutions: test (6 of 6), in-class work (2 of 6), HW (1 of 6)</td><td></td><td>Of grades on students solutions (6 of 6)</td></tr>
<tr><td>That students work on problems (HW) (4 of 6)</td><td>Of appropriate example solutions (6 of 6)</td></tr>
<tr><td>By arranging class time for small group work (4 of 6)</td><td></td><td>Of peer coaching (4 of 6)</td></tr>
<tr><td></td><td>That students come to office hours (3 of 6)</td><td>Of instructor coaching (4 of 6)</td></tr>
<tr><td rowspan="3">Looking/Listening (Path C)</td><td></td><td></td><td>Of solving problems on the board during lecture to convey information (6 of 6)</td></tr>
<tr><td></td><td></td><td>Of talking about problem solving techniques (4 of 6)</td></tr>
<tr><td></td><td></td><td>Of solving problems on the board during lecture to develop student interest (2 of 6)</td></tr>
</table>

Conclusion (so far)

- Faculty seem to see their job as setting up situations in which students can learn (providing resources, not setting constraints)
  - Students are expected to take responsibility for their own learning (similar to findings of Gallagher & Tobin, 1987)
  - Implication → Faculty will likely be reluctant to use curricular materials/methods that place more emphasis on setting constraints

- Faculty did not talk much about what students need to do to learn
  - They appear to think that path B (student uses feedback while/after solving problems) is the most effective way to learn, but don't give many details.
  - Implication → Faculty may lack an explicit understanding about how students learn (similar to findings of Prosser & Trigwell, 1999)

The Resource of
Example Problem Solutions

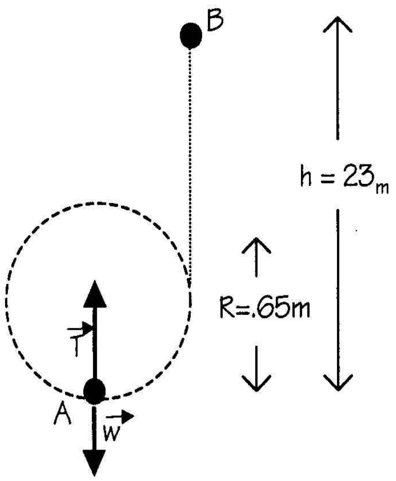
- **All six instructors described their management related to this resource as:**
  - **Assigning test or homework problems for students to work on and then provide written solutions**

    (path B – working and then using feedback)
    - **Instructors think that students will learn by comparing these EPS to their test/HW solutions –**

      but, they don't believe students do this
    - **Instructors don't attempt to manage the situation further**
  - **Working example problems (that students have not previously seen) on the board during lecture**

    (path C – looking)
    - **Instructors don't talk much about what students do in this situation or how this leads to learning**
    - **Instructors don't attempt to manage the situation further**

"Bare-Bones Solution"



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:

$$\vec{T} - \vec{w} = m\vec{a}$$

$$T - w = mv_A^2/R$$

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

"Emphasis on Details"

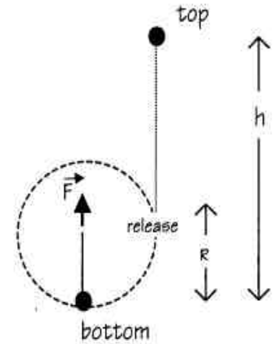
Each step explicitly written and goal clearly stated

Include clarifying comments

Instructor solution II

Known:
- $w = 18N$ = weight of stone
- $R = 0.65m$
- $h = 23m$
- $v_t = 0$ = velocity at top

Unknown:
- $v_r = ?$ = velocity at release
- $v_b = ?$ = velocity at bottom
- force my hand exerts = F=?



Step 1) Find v_r needed to reach h

$E_i = E_f$

$E_{release} = E_{top}$

$PE_{release} + KE_{release} = PE_{top} + KE_{top}$

$\cancel{m}gR + \cancel{m}v_r^2/2 = \cancel{m}gh + \cancel{\cancel{m}v_t^2/2}$ 0

$v_r^2 = 2g(h - R)$

Conservation of energy for the stone earth system, since no external forces.

Note: you could also choose other systems.

KE of earth estimated to be 0

You could also use kinematics to find v_r

Step 2) Find v_b needed to have v_r at release

$E_{bottom} = E_{release}$

$PE_{bottom} + KE_{bottom} = PE_{release} + KE_{release}$

$\cancel{m}g0 + \cancel{m}v_b^2/2 = \cancel{m}gR + \cancel{m}v_r^2/2$

Conservation of energy for the stone earth system. Since T⊥v in circular path, T does no work.

Using v_r from above:

$V_b = [2gh]^{1/2}$

Step 3) Find T_b, tension at bottom, needed for stone to have v_b at bottom

$\sum \vec{F} = m\vec{a}$

$\sum F_R = ma_R$

$T_b - w = m\,v_b^2/R$

Free body diagram

To relate the forces to velocity we can look at the radial component, and use $a_R = v^2/R$.

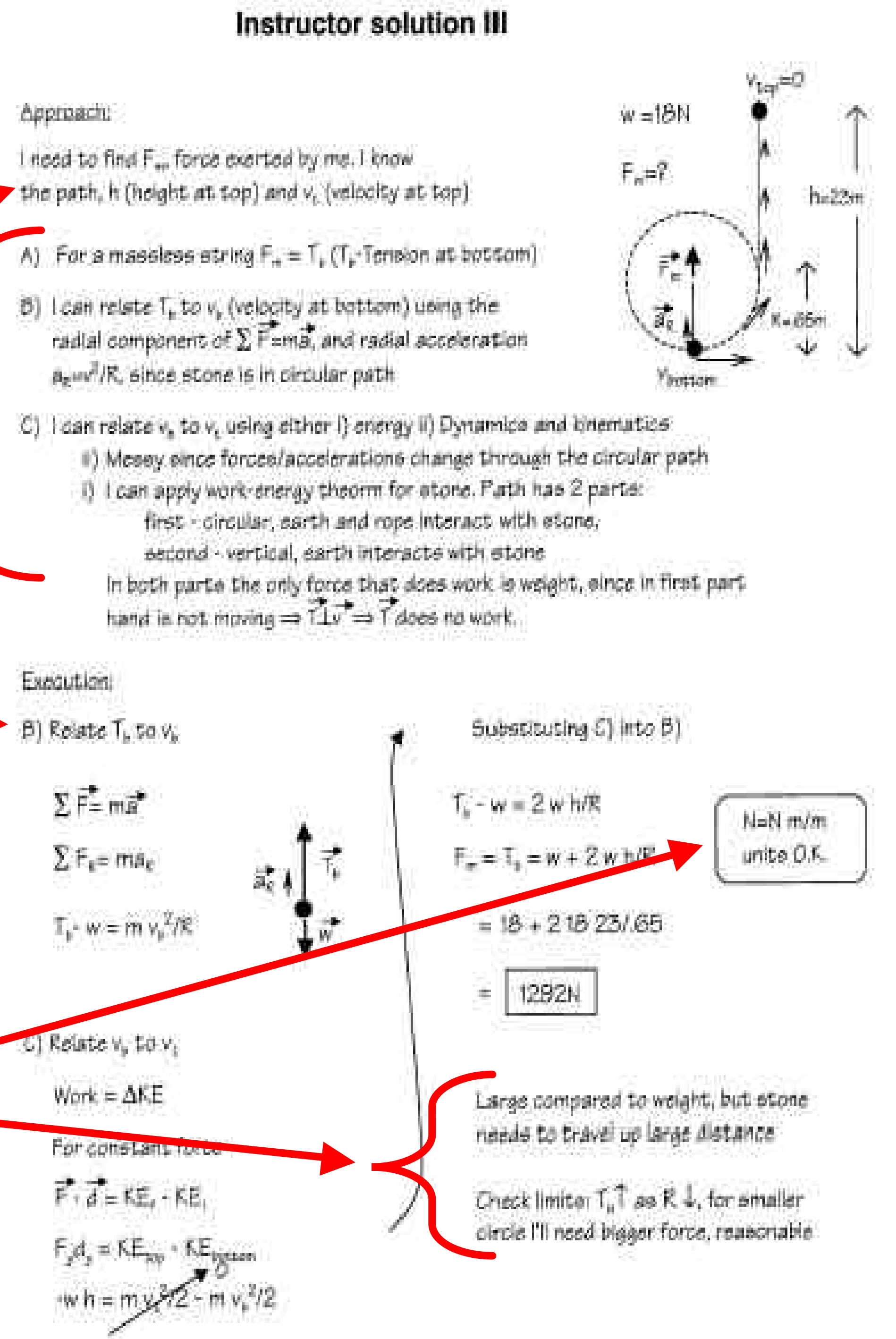
Using v_b from above:

$T_b - w = 2\ mgh/R$

$T_b = w + 2\ w\ h/R = 18 + 2\ 18\ 23/.65 = \boxed{1292N}$

T_b equals F, the force my hand exerts, for a massless string

"Emphasis on Reasoning"



Instructor solution III

Approach:

I need to find F_H, force exerted by me. I know the path, h (height at top) and v_t (velocity at top)

A) For a massless string $F_H = T_b$ (T_b-Tension at bottom)

B) I can relate T_b to v_b (velocity at bottom) using the radial component of $\sum \vec{F} = m\vec{a}$, and radial acceleration $a_R = v^2/R$, since stone is in circular path

C) 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:

first - circular, earth and rope interact with stone,

second - vertical, earth interacts with stone

In both parts the only force that does work is weight, since in first part hand is not moving $\Rightarrow \vec{T} \perp \vec{v} \Rightarrow \vec{T}$ does no work.

$v_{top} = 0$

$w = 18N$

$F_H = ?$

$h = 23m$

$R = .65m$

v_{bottom}

Execution:

B) Relate T_b to v_b

$\sum \vec{F} = m\vec{a}$

$\sum F_R = m a_R$

$T_b - w = m v_b^2/R$

C) Relate v_b to v_t

Work = ΔKE

For constant force

$\vec{F} \cdot \vec{d} = KE_f - KE_i$

$F_y d_y = KE_{top} - KE_{bottom}$

$-w h = m v_t^2/2 - m v_b^2/2$

Substituting C) into B)

$T_b - w = 2 w h/R$

$F_H = T_b = w + 2 w h/R$

$= 18 + 2 \cdot 18 \cdot 23/.65$

$= \boxed{1292N}$

N=N m/m units O.K.

Large compared to weight, but stone needs to travel up large distance

Check limits: $T_b \uparrow$ as $R \downarrow$, for smaller circle I'll need bigger force, reasonable

Restating the question in physics terms

Planning the solution – including reasoning for each step

Starts from the target quantity (Tension)

Evaluation of final answer

Providing Resources of Example Problem Solutions

- **All 6 instructors:**
  - **Distinguish between:**
    - **less detailed solution (IS1)**
    - **more detailed solutions (IS2, IS3)**
  - **Favored using solutions more detailed than IS1**
- **4 of the 6 instructors:**
  - **Said that their solutions were similar to IS1**

Factors Affecting an Instructor's Choice of Example Problem Solutions

	Less Detailed (IS1)	More Detailed (IS2, IS3)
How will it affect student learning?	• Students who were not able to do the problem might not be able to understand the solution (1 of 6)	• Makes it clear what is happening so students who had trouble can understand (6 of 6) • Can confuse students by discussing complications that some will not think of (3 of 6)
Will students use it?	• Makes the solution seem easier so students might read it (2 of 6)	• Can scare off students by having too many steps (4 of 6)
How hard is it to create?	• Easy to write or find in solution manual (4 of 6)	• I'm not good at spelling things out in detail like that (1 of 6)

What Types of Details do Instructors Prefer?

5 of the 6 instructors favored IS3 (over IS2)

IS2 (Emphasis on Details)	IS3 (Emphasis on Reasoning)
•Clear Steps	•Plans before execution
•Starts from known quantity	•Evaluates answer
•Jumps right in with calculations	•Explains reasoning
•Systematic approach implies that there is a standard way to do problems	•Starts from target quantity

Instructor Solution 3 Has Features of Expert Problem Solving

Features of Expert Problem Solving in Instructor Solution 3:	Instructors 1	2	3	4	5	6
1. Restates problem in physics terms						
2. Starts from target (goal) quantity	✓					
3. Plans first then executes	✓		✓	✓	?	?
4. Evaluates answer			✓			✓

All features of expertise noticed were described as desirable

Conclusions – Faculty Management

- Faculty do little to actively manage student use of problem solutions – they simply provide the resource of example problem solutions.
- Faculty consider three factors when deciding what types of solutions to use:
  - How hard is it to create the solution? (Good predictor of use)
  - How will the solution affect student learning?
  - Will students use the solution?

Conclusions – Resource of Example Problem Solutions

- Faculty are dissatisfied with the solutions that they currently use.
- Implications: This is an opportunity for curriculum developers to influence the current practice by developing solutions that:
    - Make reasoning clear (especially by showing planning)
  - But are not
    - Too complicated → Confuse students
    - Too long → Scare students

Conclusions – Features of Expertise

- Faculty value features of expertise that they recognize in problem solutions.
- Faculty do not appear to recognize all features of expertise in problem solutions.
  - Many notice planning before execution
  - Few notice restating the problem in physics terms
  - Some notice:
    - starting from target quantity
    - evaluating answer
- Implications: Faculty may be unable to model features of expert problem solving in their problem solutions. (Similar to research on expertise -- experts solve problems with little conscious thought and have trouble making their thinking explicit – see Dreyfus & Dreyfus, 1986.)

Summary

- It's important to find out about faculty conceptions because these conceptions strongly influence their instructional choices.
- Based on the initial model developed from a detailed analysis of 6 University of MN professors:
    - Faculty seem to see their job as setting up situations in which students *can* learn (providing resources, making suggestions) rather than setting constraints that require students to do certain things.
    - Faculty may lack an explicit understanding about how students learn.
    - Because they are expert problem solvers, faculty may not have an explicit understanding of the problem solving process. This makes it difficult for them to explain this process to students.

Summary - Continued

- Faculty consider three factors when deciding what types of solutions to use (these same three factors hold true for the other resources):
  - How hard is it to create the solution? (Good predictor of use)
  - How will the solution affect student learning?
  - Will students use the solution?

The End

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