



Physics Faculty Aren't Blank Slates Either: An Example of the Mismatch Between Physics Faculty Conceptions and Research- Based Instructional Strategies*

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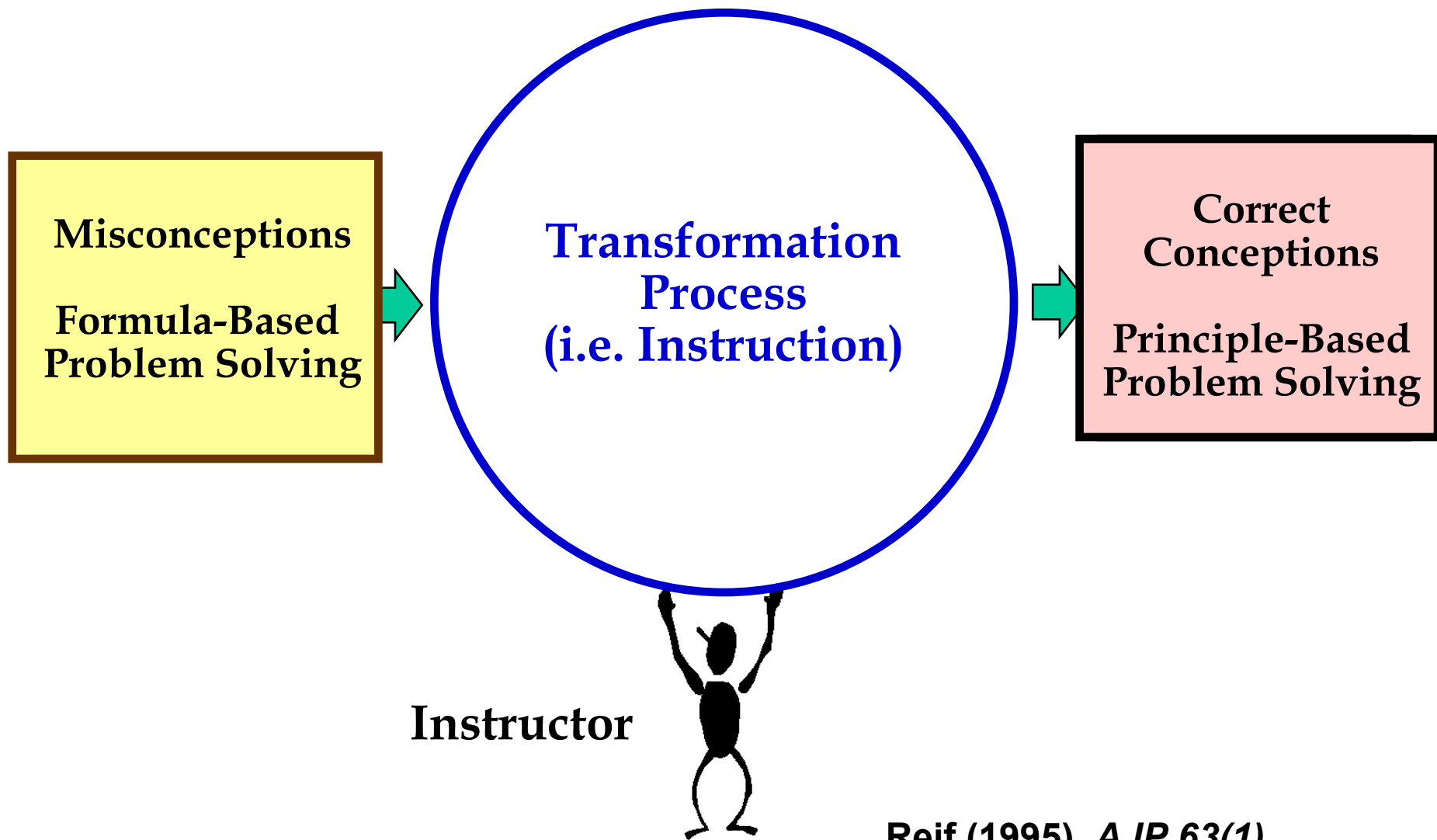


Overview

1. **The Larger Study - Why study faculty conceptions?**
2. **Research Methods**
3. **An Example From Grading**
 - a) **Results - What conceptions do faculty have?**
 - b) **Implications - How do these conceptions compare with the conceptions required to successfully use research-based instructional strategies?**



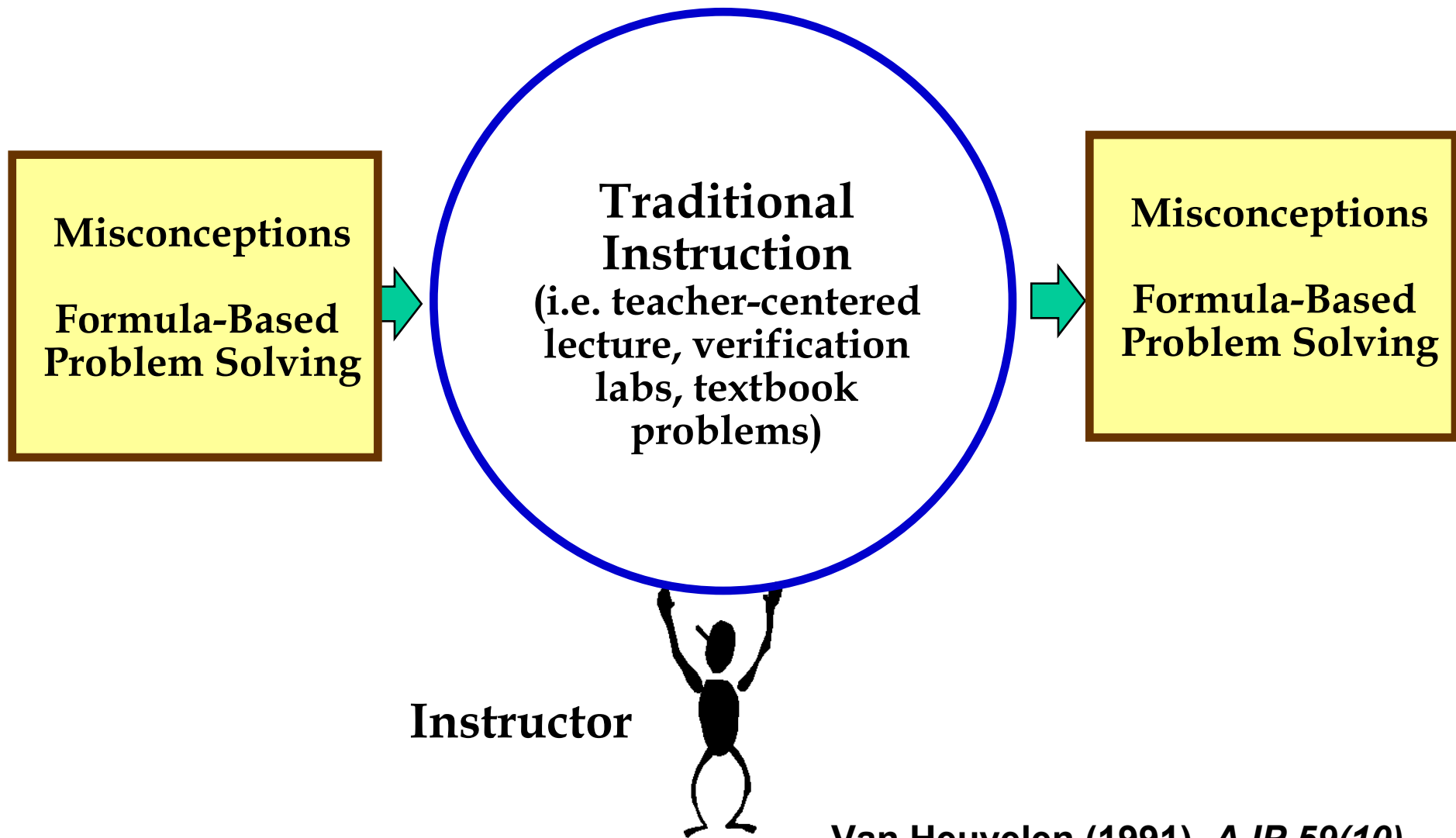
The Instructional Problem





Traditional Introductory Physics

Transformation Process

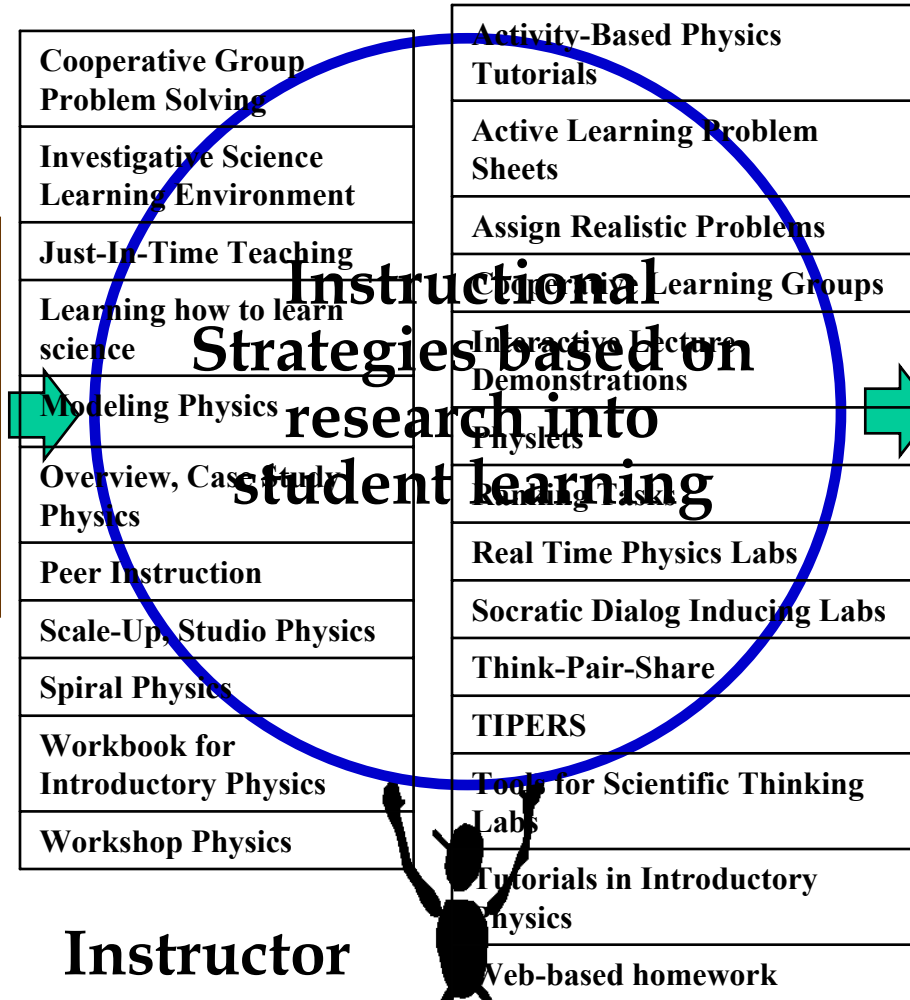




Research-Based Introductory Physics

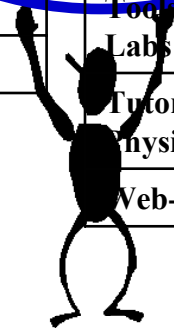
Transformation Process

Misconceptions
Formula-Based
Problem Solving



Correct
Conceptions
Principle-Based
Problem Solving

Instructor





Why don't more faculty stop using traditional instruction and start using research based curricular materials?

- Our theory: The available curricular materials are not consistent with faculty conceptions (i.e. beliefs, values, knowledge, etc.) of teaching and learning
- If this is the case then we need to either:

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.



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.



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



Grading Student Solutions

Grading was one of 3 concrete tasks used in the interview

- **During the interview faculty were asked to grade 5 student solutions and to explain their reasons for each grade**
- **They were also asked to describe what they liked and disliked about each of the solutions**

Why grading?

- **All faculty grade student solutions
(or at least supervise grading)**
- **Concrete task that can focus the faculty and elicit their values**
- **Important because it sends messages to students**



Faculty Conceptions/Practices Related to Grading

Big Questions about faculty conceptions related to grading?

1. How do faculty conceptions compare with conceptions required to successfully use research-based instructional strategies?
2. If there are differences,
 1. Are these differences important?
 2. Is it possible to design research-based instructional strategies that are still effective at promoting student learning, but that don't conflict with faculty conceptions?
 3. If not, what information do we have that might help us change these conceptions
 1. Do faculty have conflicting conceptions about grading?
(maybe use disequilibrium and accommodation)
 2. Do faculty have conceptions that can be built on (maybe use p-prims, bridging analogies)

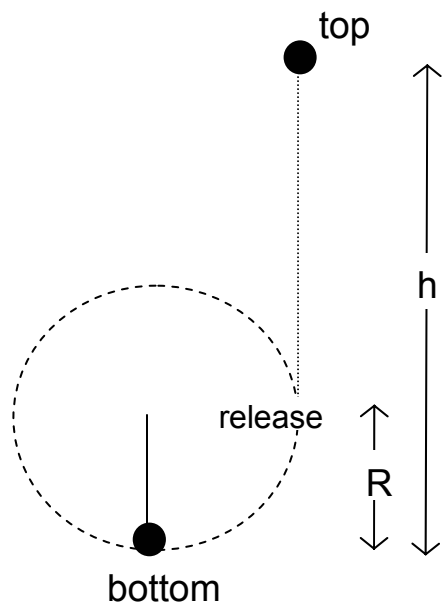


Problem Used in the Interview

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.



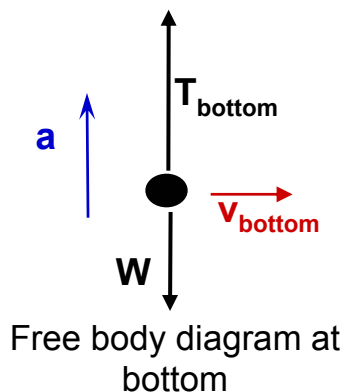
An Expert Solution



No work is done by string (since $T \perp v$), so all work is done by gravity. Using conservation of energy between bottom and top:

$$\frac{1}{2}mv_{bottom}^2 = mgh$$

Using Newton's 2nd Law at the bottom.



$$T_{bottom} - mg = m \frac{v_{bottom}^2}{R}$$

$$T_{bottom} = 1292 \text{ N}$$



Your Turn

Time: 3-4 minutes

Instructions:

- **Assign grades to the two student solutions**
 - **Use a scale of 0 - 10 points**
 - **Grade as if these were your students**

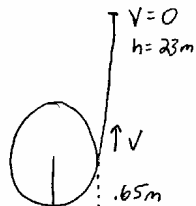
(These are two of the five solutions used in the interview)

- **Then, turn to your neighbor and discuss your **reasons** for grading the way you did.**



Student Solutions D and E

Student Solution D



Energy conservation between top and bottom

$$\frac{1}{2}mv^2 = mgh$$

$$v^2 = 2gh$$

$$v = \sqrt{2(-9.8)23}$$

$$v = 21.2$$

Uses h instead of $h-R$

makes sign error

changes sig

between release and bottom $T \perp v$ so no work done

\therefore Energy is conserved and velocity is the same

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

$$T - mg = \frac{mv^2}{R}$$

$$T = 18 + \frac{18}{9.8} \cdot \frac{21.2^2}{0.65}$$

$$= 1292\text{N}$$

uses v_{release} instead of v_{bottom}

Student Solution E

$$V^2 = 2gh$$

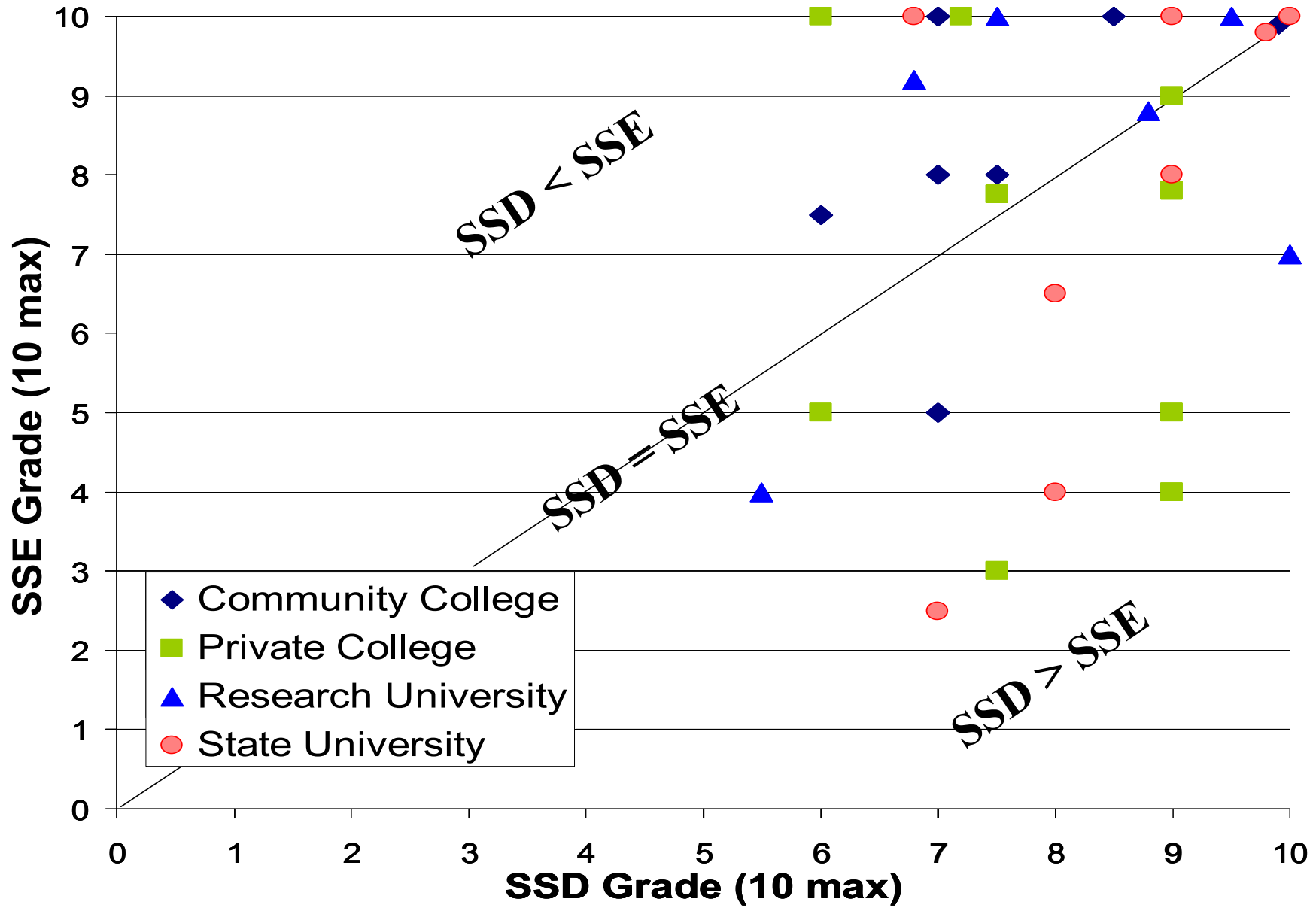
$$F - mg = \frac{m2gh}{R}$$

$$F = 18 + \frac{2 \cdot 18 \cdot 23}{0.65} = 1292\text{N}$$

SSE could have been thinking the same thing as SSD.



How did Interviewees Grade?





Looking at 6 Research University Faculty

- Statements made during the grading portion of the interview were categorized.
- Three distinct themes emerged:
 1. Instructors say that they want to see reasoning in student solutions so that they can know if a student really understands.
 2. Instructors indicate a reluctance to deduct points from a student solution that *might* be correct as well as a willingness to deduct points from a student solution that is clearly not correct.
 3. Instructors tend to project correct thought processes onto a student solution when the student does not explicitly describe his/her thought processes.
- Most instructors expressed all three themes.



Theme 1: Instructors say that they want to see reasoning in student solutions so that they can know if a student really understands.

Instructor 1: “This one [SSE] is obviously a potentially perfect solution. No explanation so, at this level, considering other solutions, it’s not clear whether this is derived from a formula-like approach. This one it’s not clear, he may have solved similar problems so he knows where he’s going. Shows no understanding, I can’t tell whether he has full understanding or is being sloppy, or not really understanding but just memorized some problem.”

Instructor 6: “As I said, it’s hard to say whether this guy [SSE] is copying formulas out of a book or thinking, which of course is the problem with these types of solutions. I usually would tell people, counsel them away from this type of solution in a class. You know, I would say that this is like a written thing that you’re trying to tell the story and you should explain what you’re trying to do in applying these various things.”



Theme 2: Instructors indicate a reluctance to deduct points from a student solution that *might be correct* as well as a willingness to deduct points from a student solution that is clearly not correct.

Instructor 5: “I mean, this one’s [SSE] correct. There’s nothing in here that’s wrong. $v^2=2gh$ [reading from SSE]. Yeah, I mean it’s not clear what v is, but of course in the end the equation would become this because at the top the velocity is zero, so you could get to that. And this one, again the student [SSE] doesn’t explain where she or he got this from, but in fact you could get to this by substitution, mv^2/r , there’s a 2 there, and then, yeah. So I mean this one you have to give full credit, at least I would give full credit to. It [SSE] has the right answer. It has elements of the right method. And it doesn’t say anything wrong and it doesn’t say anything stupid.”

Instructor 4: “The fact that this [SSD] comes up with the right answer is coincidental. On the other hand the student will complain that she or he didn’t get full credit and he got the right answer, something like that. So you’d have to, I would take off some.”



Theme 3: Instructors tend to project correct thought processes onto a student solution when the student does not explicitly describe his/her thought processes.

Instructor 2: "This guy, student E, had in mind exactly what I had in mind, namely we have conservation of energy, so that gives me the velocity, then he sees that the centripetal force is mv^2 over R , so having found v^2 by conservation of energy, he substitutes in, he says now it's a centripetal force problem, and Bang, out comes the answer."

Instructor 4: "Not as neatly done as you would really like [SSD], but I mean the essence is here. It's got energy conservation. Kinda thinking about it in reverse, you know, which is perfectly ok. I mean, the reasoning would be, it's the same problem if I start down here with some speed and I go up there, as if I start up here and go back down. Doesn't say that, but I think that's the thinking."



Each Theme Can Suggest a Different Grade

Student Solution E

$$V^2 = 2gh$$

$$F - mg = \frac{m 2gh}{R}$$

$$F = 18 + \frac{2 \cdot 18 \cdot 23}{.65} = 1292 \text{ N}$$

Theme 1: Wanting to see reasoning.

Theme 2: Not wanting to deduct points from a solution that might be correct

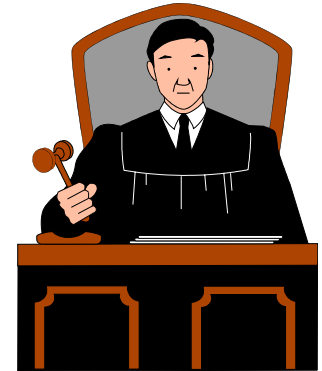
Theme 3: Projecting correct thought processes

**Low
Grade**

**High
Grade**



Burden of Proof Determines Which Theme Dominates



Burden of Proof on the Instructor: The instructor has to be able to demonstrate that the student used incorrect knowledge or followed incorrect procedures in order to deduct points.

Burden of Proof on the Student: The student has to demonstrate that he or she used correct knowledge and followed correct procedures in order to get points.

Instructors were consistent in where they placed the burden of proof.



Three Possible Orientations Towards Grading

	A: Burden of Proof on the Instructor	B: Burden of Proof on the Student	C: Burden of Proof on the Student
Judged Object	Student's Understanding	Student's Understanding	Student's Argument
Role of Instructor	Find evidence for incorrect knowledge and/or procedures and deduct appropriate points	Find evidence for correct knowledge and/or procedures and give appropriate points	Find evidence for correct argument and assign appropriate points
Assumption	The student possesses the correct knowledge unless shown otherwise	The student possesses incorrect knowledge unless shown otherwise	A student who writes a good argument possesses the correct knowledge.
	5 Instructors	1 Instructor	0 Instructors



Grading SSE

Student Solution E

$$V^2 = 2gh$$

$$F = mg = \frac{m \cdot 2gh}{R}$$

$$F = 18 + \frac{2 \cdot 18 \cdot 23}{.65} = 1292 \text{ N}$$

A: Burden of Proof on the Instructor

B: Burden of Proof on the Student (Show Understanding)

C: Burden of Proof on the Student (Show Argument)

Theme 1 Reasoning

The student might not have done the problem correctly

No evidence that the student did the problem correctly.

No argument that leads to the final result.

Theme 2 Might be correct

No evidence that the student did anything wrong.

The student may have done the problem correctly.

The statements could be fit into a correct argument.

Theme 3 Projecting

I believe that the student did the problem correctly.

(not relevant)

(not relevant)

Resolution

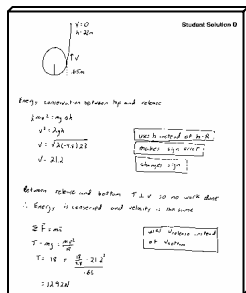
T1 < T2, T3
a) T1 not considered - full credit
b) T1 leads to small deduction

T1 > T2, few points given

T1, T2 suggest same grading. Few, if any, points given



Grading SSD



A: Burden of Proof on the Instructor

B: Burden of Proof on the Student (Show Understanding)

C: Burden of Proof on the Student (Show Argument)

Theme 1 Reasoning

The student clearly made some mistakes.

The student has a sense of direction. Many things done correctly.

An argument structure is present and can be followed.

Theme 2 Might be correct

Some details implemented incorrectly.

Some things done incorrectly.

Some parts of the argument were faulty.

Theme 3 Projecting

The student basically understands how to do the problem.

(not relevant)

(not relevant)

Resolution

T1, T2, T3 suggest same grading. A few points deducted for some incorrect things. (SSD < SSE)

T1, T2 suggest same grading. Points given for parts of solution that are correct. (SSD > SSE)

T1, T2 suggest same grading. Points given for good structure, not full points -- parts of the argumentation were faulty. (SSD > SSE)



1. How do faculty conceptions compare with conceptions required to successfully use research-based instructional strategies?

A:

Burden of Proof on the Instructor

Most Faculty

Why?

Want to be fair

Pressure from students

B:

Burden of Proof on the Student (Show Understanding)

Research-Based Instructional Strategies

Why?

helps students learn

- **Forces students to think about their reasoning**
- **Helps teachers identify student difficulties**

C:

Burden of Proof on the Student (Show Argument)

Leonard et. al. (1996). "Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems." *AJP*, 64, 1495-1503.

Heller et. al. (1992). "Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving." *AJP*, 60, 627-636.

Van Heuvelen (1991). "Overview, Case Study Physics." *AJP*, 59, 898-907.



2. If there are differences, Are these differences important?

Yes, Because Grading Sends Messages to Students*

Initial Student Behavior

Students show little reasoning on problem solutions.

Instructor Grading Orientation

Burden of Proof on Instructor

Burden of Proof on Student

Resulting Grading

As more reasoning is shown, there is more opportunity for the instructor to deduct points.

Points only given when the correct physics is explained by the correct reasoning.

Message Sent to Students

Students may receive more points if they don't show their reasoning

Students cannot get points without showing their reasoning.

Effect on Student Behavior

Students are discouraged from showing their reasoning.

Students are encouraged to show their reasoning.



Faculty Conceptions/Practices Related to Grading

Big Questions about faculty conceptions related to grading?

1. How do faculty conceptions compare with conceptions required to successfully use research-based instructional strategies?

**They're
Different**

2. If there are differences,

1. Are these differences important? **Yes**

2. Is it possible to design research-based instructional strategies that are still effective at promoting student learning, but that don't conflict with faculty conceptions?

**Maybe, But
I don't
know how**

3. If not, what information do we have that might help us to change the faculty conceptions

1. Do faculty have conflicting conceptions about grading? (maybe use disequilibrium)

2. Do faculty have conceptions that can be built on? (maybe use p-prims, bridging analogies)



Faculty have the same idea about grading as many research-based instructional strategies.

They also have two other ideas about grading – that often conflict with the first one.

Student Solution E

$$V^2 = 2gh$$

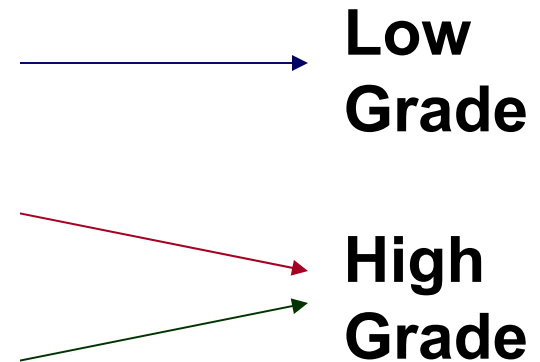
$$F - mg = \frac{m2gh}{R}$$

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Theme 1: Wanting to see reasoning.

Theme 2: Not wanting to deduct points from a solution that might be correct

Theme 3: Projecting correct thought processes





Conditions for Change -- Accommodation

1. There must be **dissatisfaction** with existing grading.

2. A new type of grading must be **intelligible** (it must make some sense).

3. A new type of grading must appear initially **plausible** (it must seem like it could work).

4. A new type of grading should be **fruitful** (it should solve more than the current problem).

1. Many instructors are not happy with their grading:



- Have a conflict between T1 vs. T2, T3 when grading
- Prefer solutions with reasoning.
- Know that students often solve problems by plug-and-chug (and that this is not really problem solving)

2. Many instructors understand that they could grade only well-reasoned solutions - in fact,



many say on their tests that solutions must show reasoning, however, tend not to follow through.

3. Instructors must believe that grading for reasoning is something that they could do (ex: grade for reasoning, but drop first exam)



4. Instructors must believe that grading for reasoning benefits students (learn physics better, engage in more realistic science tasks) and teachers (understand student difficulties, ease of grading).





What do we know about promoting Conceptual Change in Students?

The unique features of conceptual change instruction are

- 1) that students make their conceptions explicit so that they become aware of their own ideas and thinking, and
- 2) that students are constantly engaged in evaluating and revising their conceptions.

Common teaching sequence for conceptual change:

- **Reveal student preconceptions**
- **Discuss and evaluate preconceptions**
- **Create conceptual conflict with those preconceptions**
- **Encourage and guide conceptual restructuring**



What Might this Look Like for Instructors?

Common teaching sequence for conceptual change:

1. **Reveal student preconceptions**
2. **Discuss and evaluate preconceptions**
3. **Create conceptual conflict with those preconceptions**
4. **Encourage and guide conceptual restructuring**

Possible sequence for changing instructor's conceptions about grading:

1. **Use artifacts (i.e., have instructors grade sample student problem solutions)**
2. **Have instructors discuss reasons for grading.**
3. **Have instructors identify:**
 - **conflicts within their ideas about grading**
 - **Problems resulting from their grading practices**
4. **Discuss alternative ways to think about grading and different grading practices.**



Conclusion - Grading

- Most faculty appear to place the burden of proof on themselves when grading while research-based instructional strategies place the burden of proof on students.
- Most instructors also value seeing student reasoning in problem solutions – which conflicts with placing the burden of proof on instructors.
- **Implications: Curriculum developers have an opportunity to influence instructors' grading practice by highlighting this conflict and providing alternative ways to think about grading.**



The End

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