First Results from New JHU Active-Learning-Based Course in Introductory Physics

Bob Leheny

Some Background:

- 700+ JHU undergraduates enroll in introductory physics each semester.
    - Divided into two courses: one for Engineers & one for Bioscience majors.
    - Typically taught in traditional format: 1 hours/week of lecture plus 1 hour/week of TA-led recitation.
    - Historically, a Laissez-faire approach from department about instruction.
- 2011 – 2013 JHU Gateway Science Initiative.
    - University initiative to improve/innovate instruction in core courses.
    - Coincided with growing appreciation/evidence for impact of "active learning" strategies in introductory physics.
        - "Active Learning" = "flipped classroom", "peer instruction", etc.

Step 1: Research the Options

Site visits to other universities with alternative and/or innovative approaches to teaching introductory physics, including:

Tufts (PER)
MIT
Princeton
U. Minnesota (PER)
Harvard
U. Washington (PER)
NC State (PER)
Cornell

Key Outcomes:

- Expanded efforts to implement active learning in lectures
- Curriculum development based on group problem solving for recitation sections
- Creation of new course sequence devoted to active learning.

Initiation of new course in introductory physics:

Modeled on:

SCALE-UP course @ NC State & TEAL course @ MIT

Student
Centered
Activities for
Large
Enrollment
University
Physics

Technology
Enabled
Active
Learning

A key premise: Classroom architecture/technology is important

Step 1: Ditch the lecture hall

- Active participation by students possible (e.g. with “clickers”) but restricted.
- Group activities highly constrained.

Step 2: Replace with specially designed classroom:

- 7’ round tables to accommodate 3 teams of 3 students
- Audio to enable classroom-wide discussions
- 2 projector screens + 6 TV monitors
- Whiteboards around perimeter

Strategy: Get students out of their seats midway through class.

Restrict Lecturing to brief summaries that

- Review
- Motivate
- Elaborate on tricky concepts

and replace with activities

- Group Problems
- Tutorials
- Quick Questions
- Tangibles

Group Problems

- Modeled on "Context Rich" problems from Ken Heller at UMN:

A good problem:
- i) Is too challenging for a single student but not for a group.
- ii) Requires multiple steps of logic and/or physics reasoning.
- iii) Contains irrelevant information.

Example:

"Special Delivery"

You and a friend have summer jobs loading packages onto delivery trucks. The packages slide down a ramp of length 6 meters that makes a 30º angle with the horizontal. You notice that a package placed at the top of the ramp reaches the bottom in 2 seconds. Since the packages are heavy, and because you like to show off your physics knowledge, you decide to adjust the angle of the ramp so that the packages slide at constant velocity after receiving an initial nudge. At what angle do you set the ramp?

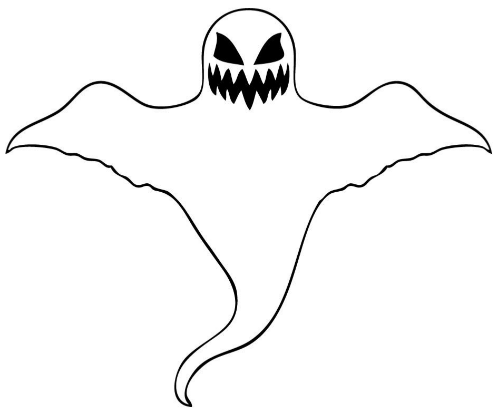
Another example group problem

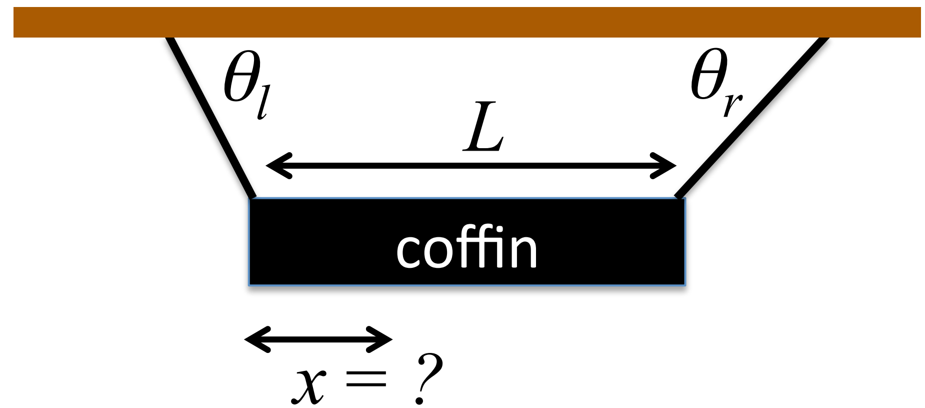
"Lone Ranger"

A wagon with two boxes of gold and having a total mass of 300 kg is cut loose from the horses by an outlaw when the wagon is at rest 50 m up a 6^o slope. The outlaw plans to have the wagon roll down the slope and then across 50 m of level ground before finally falling over a cliff into a canyon where his partners wait. But, unknown to the outlaws, the Lone Ranger (mass of 75 kg) and Tonto (mass of 65 kg) are waiting in a tree 40 m from the cliff. They time their fall so that they drop vertically into the wagon just as the wagon passes beneath them. They require 5.0 s to grab the gold and jump out of the wagon. Will they make it before the wagon goes over the cliff?

Another example group problem

“Boo”





For Halloween, you suspend a coffin of mass M and length L from the ceiling by two cables, which make angles with the ceiling θ_l and θ_r as shown. To add a bit more fright to the display, you want to hang a ghost from the coffin, but you don’t want the coffin to move as a result. Find the distance x from the end of the coffin where you should hang the ghost in terms of L, θ_l and θ_r.

Tutorials

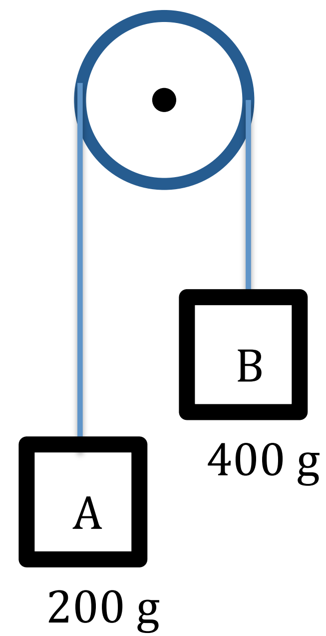
Modeled on materials developed by PER group at U. Washington.

A good tutorial:
i) Asks questions that expose common misconceptions.
ii) Requires students to explain their reasoning (in sentences).
iii) Is capable of generating debate.

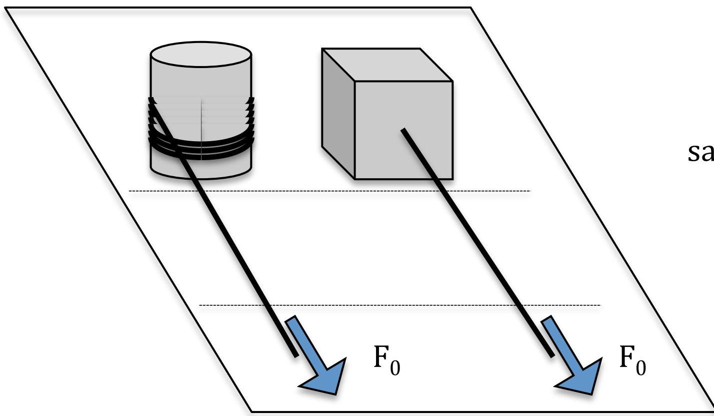
Tutorial Example:

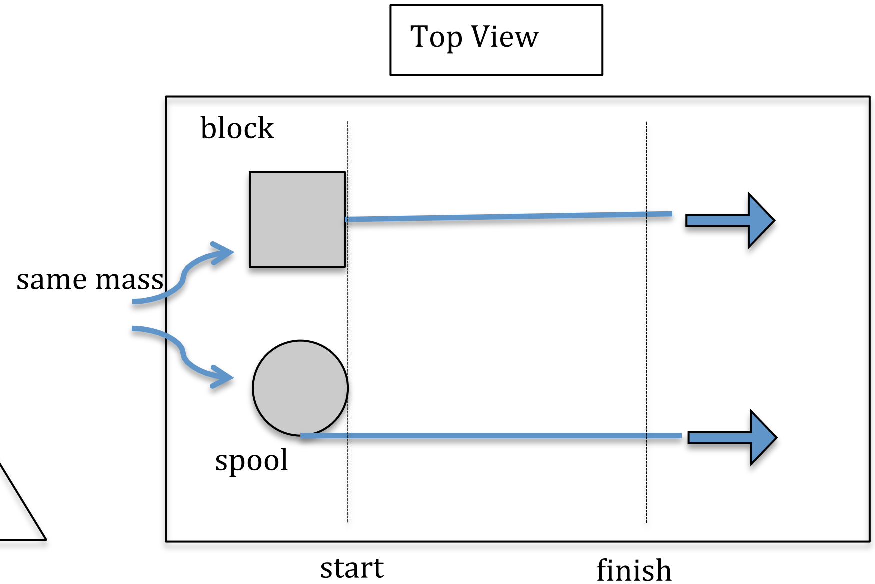
1) Compare the motion of mass A to that of mass B after they are released. Do not do use algebra. What does your answer imply about the net force on A in comparison with that on B?

2) A student makes the following statement about the Atwood's machine, "All strings can do is transmit force from other objects, so the force upward on each block is equal to the weight of the other block." Do you agree with this statement? Explain your answer.



Another tutorial example





For each student, explain what is correct and what is incorrect about their statements.

<u>Student 1:</u> *"The spool will rotate and cross the finish line at the same time as the block. They have the same mass and the same net force, so their centers of mass will have the same acceleration. It doesn't matter that the spool rotates and the block doesn't."*

<u>Student 2:</u> *"I disagree. The spool will cross after the block since some of the tension is used to rotate the spool. When a force causes a rotation, it has less effect on the translational motion."*

<u>Student 3:</u> *"I agree that the spool will rotate and cross after the block, but I was thinking about energy. They will have the same total kinetic energy when they get to the finish line. Since the spool will have some rotational kinetic energy, it must have less translational kinetic energy than the block. Therefore, it will be slower and arrive at the finish line later."*

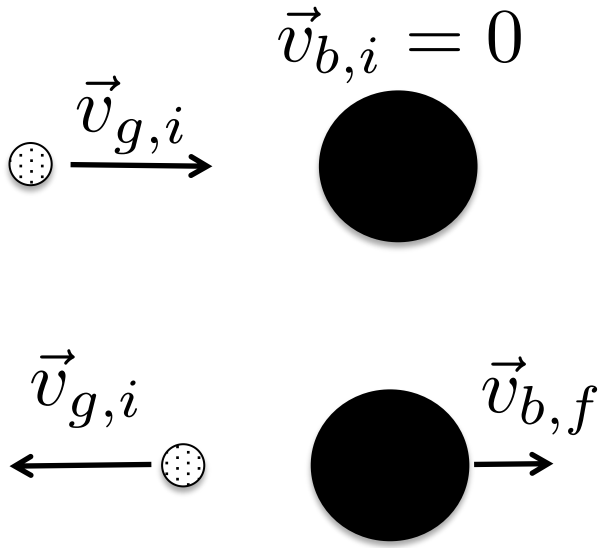
Quick Question:

A golf ball is fired at a bowling ball initially at rest and bounces back elastically. Compared to the bowling ball, the golf ball after the collision has

(A) More momentum but less kinetic energy
(B) More momentum and more kinetic energy
(C) Less momentum but more kinetic energy
(D) Less momentum and less kinetic energy
(E) The same momentum and kinetic energy

A golf ball is fired at a bowling ball initially at rest and bounces back elastically. Compared to the bowling ball, the golf ball after the collision has

(C) Less momentum but more kinetic energy



$$\vec{P}_i = \vec{p}_{g,i} = m_g \vec{v}_{g,i}$$

$$\vec{P}_f = \vec{p}_{b,f} - \vec{p}_{g,f}$$

Quick Question:

A hockey puck is sliding along the ice at a constant velocity of 0.5 m/s when it slides onto a rough, sandy patch. The puck comes to rest after traveling a distance of 1 meter along the patch. A second, identical puck slides onto the patch with an initial velocity of 1 m/s. How far does the second puck travel before coming to rest?

A) 1 m

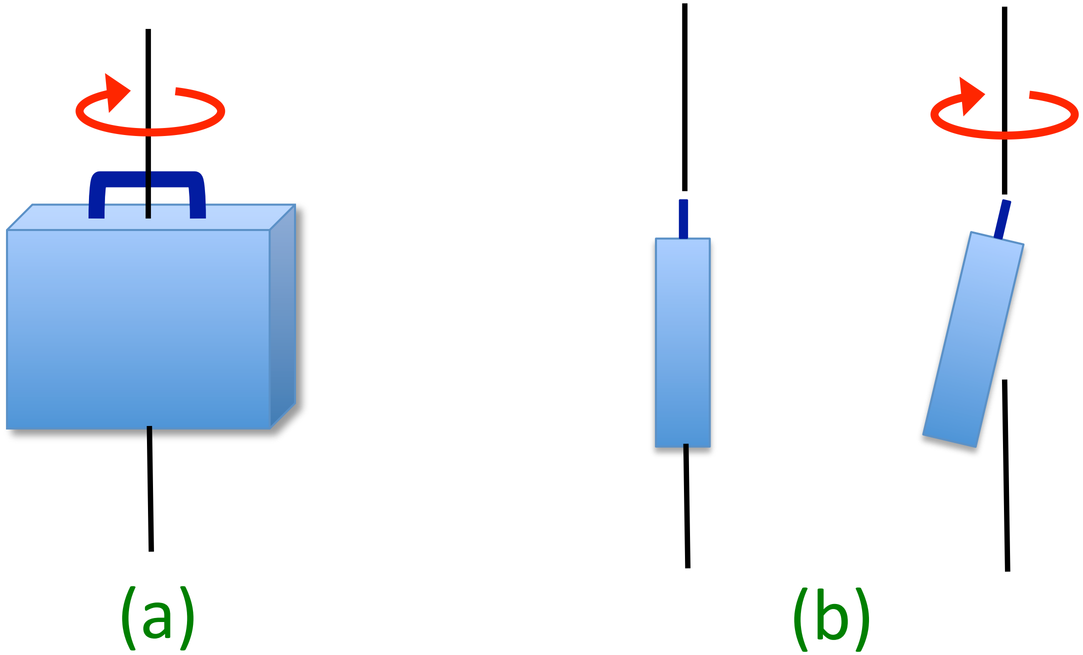
B) 2 m

C) 3 m

D) 4 m

E) 8 m

Worst Quick Question Ever...

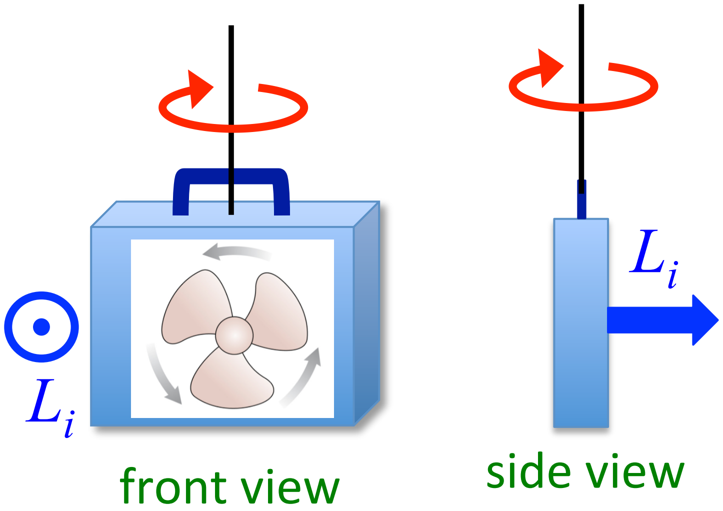


A suitcase containing a spinning flywheel is rotated about the vertical axis as shown in (a). As it rotates, the bottom of the suitcase moves out and up, as in (b). From this we can conclude that the flywheel, as seen from the side of the suitcase as in (a), rotates

(A) clockwise

(B) counter-clockwise

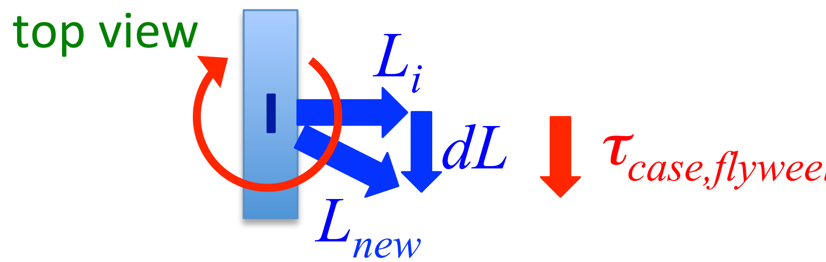
Quick Question



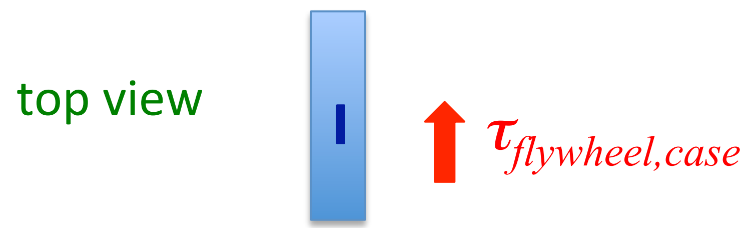
(A) clockwise

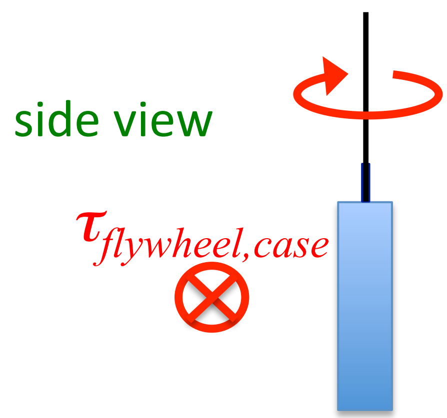
(B) counter-clockwise

Rotating flywheel changes angular momentum direction and hence must involve a torque on the flywheel:

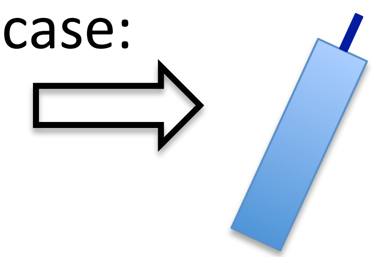


So, by Newton's 3[rd] Law:





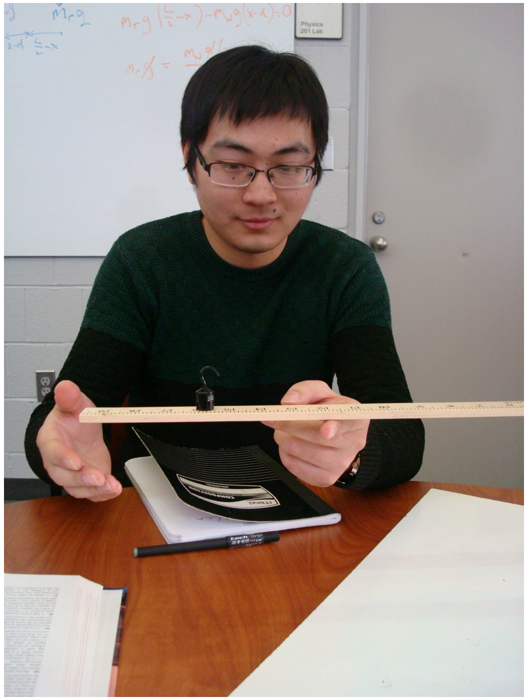
Torque rotates case:



NB: You can do the experiment at the Maryland Science Center.

Tangibles

- Designed to take 15-20 minutes.
- Often very low-tech.
- Integrated into class time along with group problems, conceptual questions (clicker questions), and faculty-led discussions.
- Examples:



Statics: find the weight of a ruler

Wave propagation along a slinky

Lesson Learned: Successful tangibles typically require students first to make a prediction, often based on a calculation, then perform a simple measurement to test the prediction.

Roles in Group Problem Solving

Manager: Directs the sequence of steps in the problem, manages time, ensures that each group member participates, keeps group focused on task.

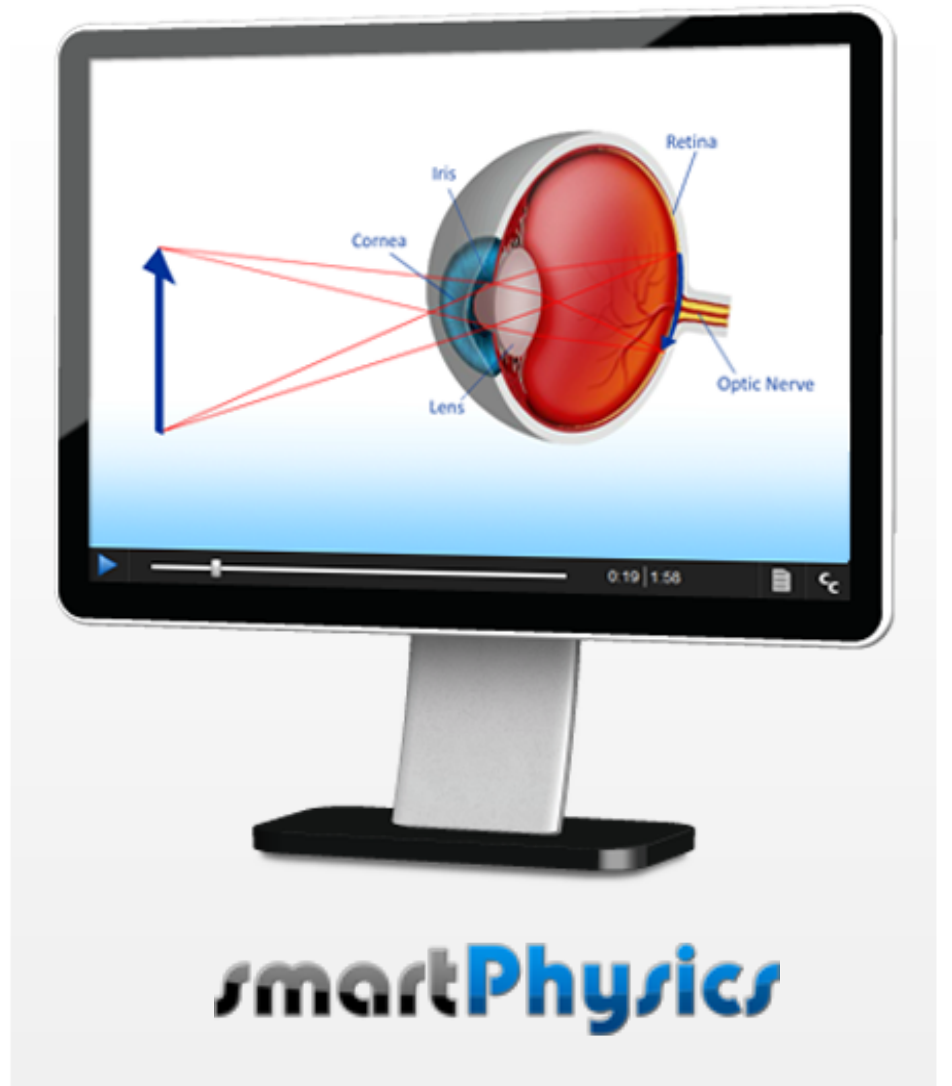
Recorder: Writes down actual steps, checks for understanding of all group members, makes sure all team members agree on steps, submits written work for the group.

Skeptic: Makes sure all possible problem-solving strategies are explored, suggests alternative approaches or concerns with suggested solutions, ensures interpretation of problem and solution are correct.

Key Ingredient: Students come prepared

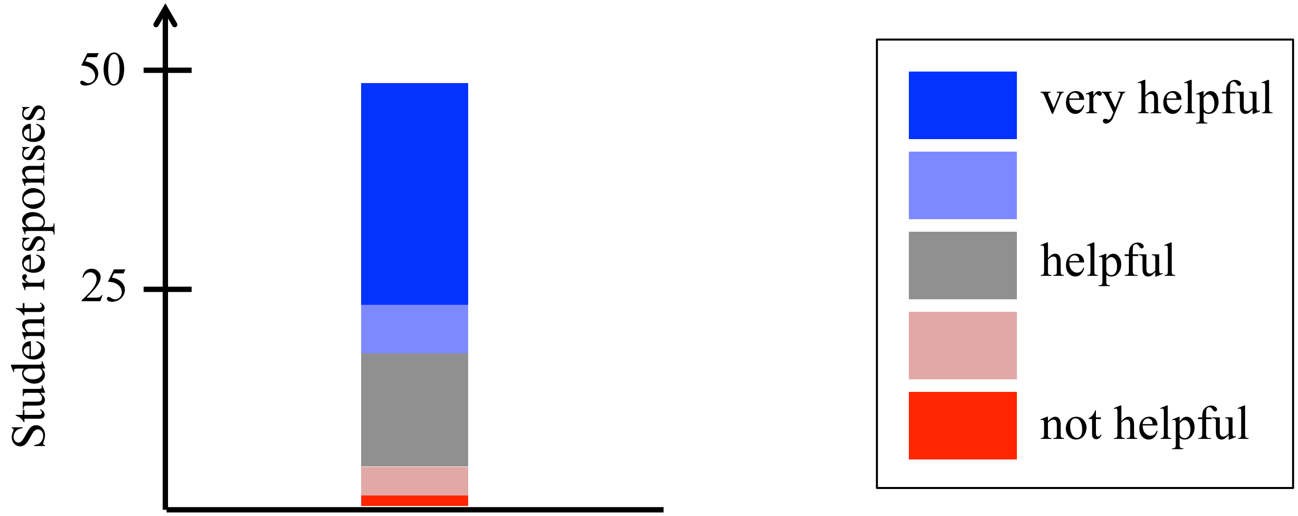
SmartPhysics Prelectures:

- 20-30 minute animated video before each class.
- Several required "checkpoint" questions to answer along the way.
- Opportunity for student feedback.



Key Observation: Students watch the pre-lectures!

- Instructor has "big brother" capabilities:
    - 80% of students watch; submit checkpoint responses appropriately spaced in time
    - 25% of students watch multiple times.
- Student opinions of pre-lectures:



Some Early Assessment (fall 2013):

Diagnostic Test (FCI):

	SCALE-UP course	Auditorium course
Pre-test	60.7%	63.2%
Gain	0.27	0.25

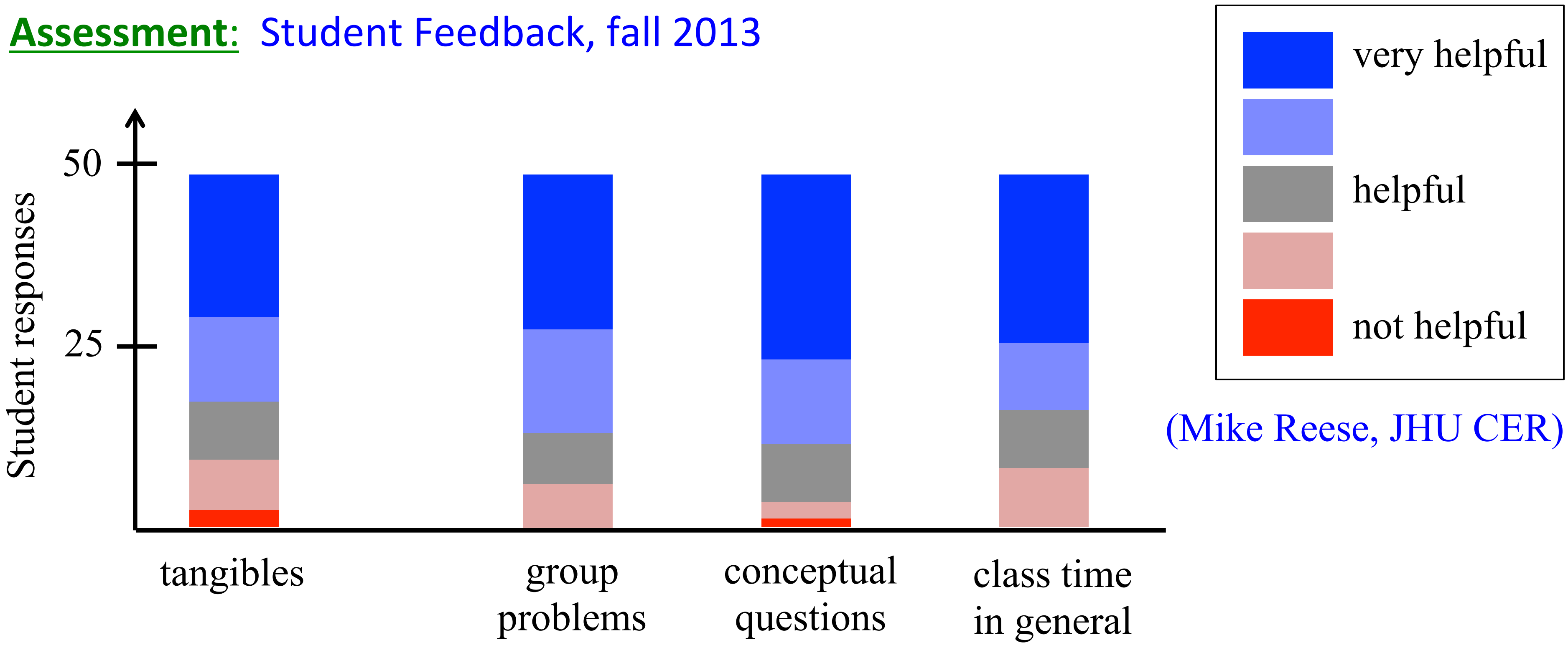
NB: gain in typical lecture course: 0.2

Exam Scores:

	SCALE-UP course	Auditorium course	
Midterm 1	74.8%	73.9%	+0.9%
Midterm 2	67.4%	65.9%	+1.5%
Midterm 3	66.6%	63.8%	+2.8%
Final Exam	63.3%	62.2%	+1.1%

Conclusion: students in SCALE-UP displayed marginally weaker preparation, but performed slightly better on exams.

Assessment: Student Feedback, fall 2013



(Mike Reese, JHU CER)

Conclusion: Most students found the tangibles helpful or very helpful for learning, but not especially so.

Plans:

Revise tangibles to combine them more closely with problem-solving exercises.

Assessment: Student enrollment

Enrollments:

Fall 2013 (Physics I):	47
Spring 2014 (Physics II):	60 (32 from fall course).
Fall 2014 (Physics I):	76

The experiment continues starting August 28....