Active Learning with *Interactive Lecture Demonstrations*

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University of Oregon

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Tufts University

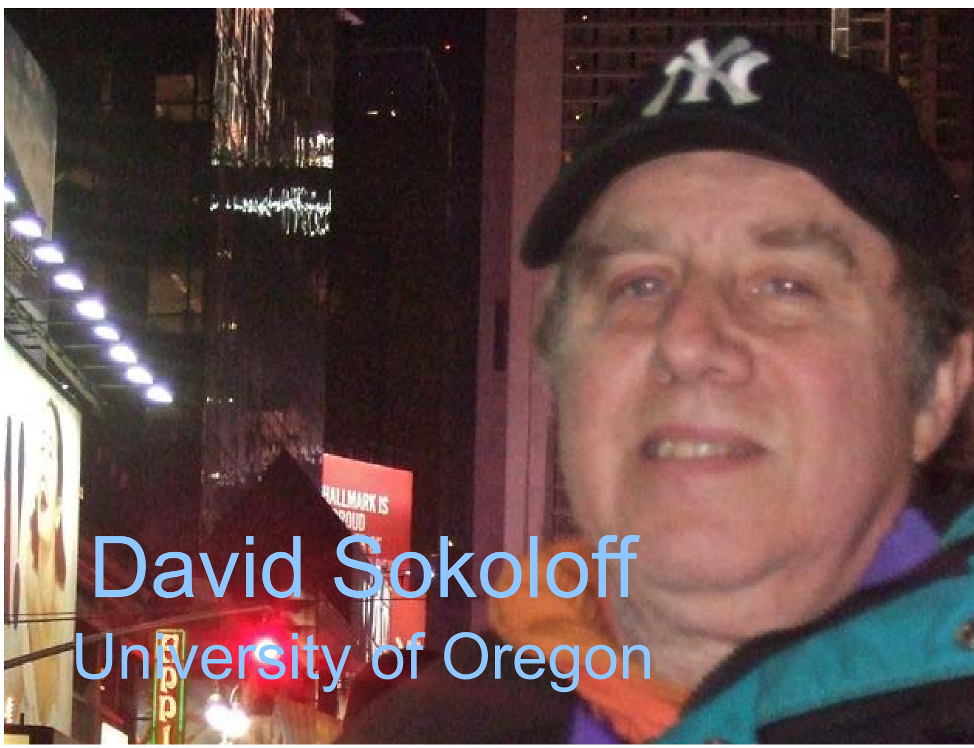
New Faculty Workshop
American Center for Physics
June 13, 2017

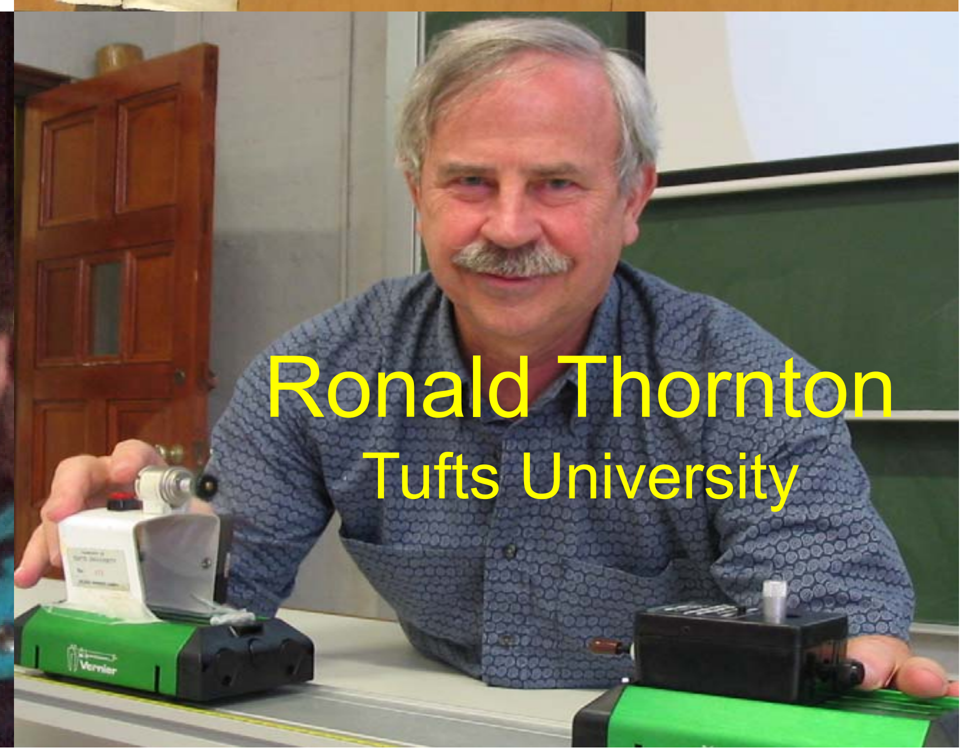
Activity Based Physics

Integrating Physics Education Research with Technology

31 years of physics education research, development and dissemination.

Winner of the *2010 APS Excellence in Physics Education Award*





Thank you to:

National Science Foundation
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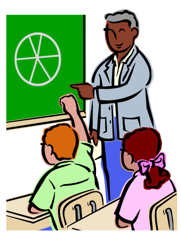

U.S. Department of Education
FUND FOR THE IMPROVEMENT OF
POST-SECONDARY EDUCATION (FIPSE)

The Problem . . .

I will not learn concepts in physics class

I will not learn concepts in physics class

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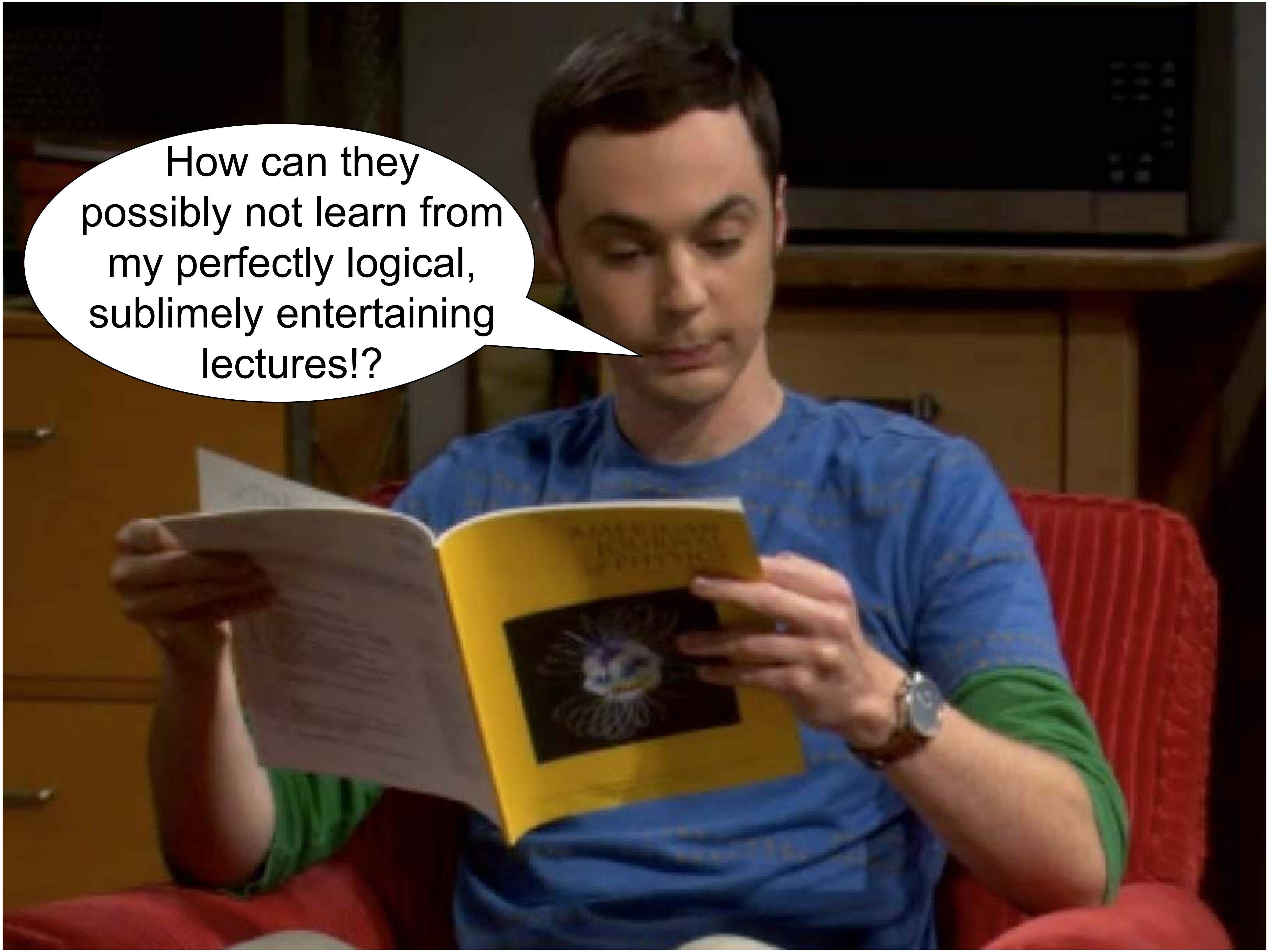
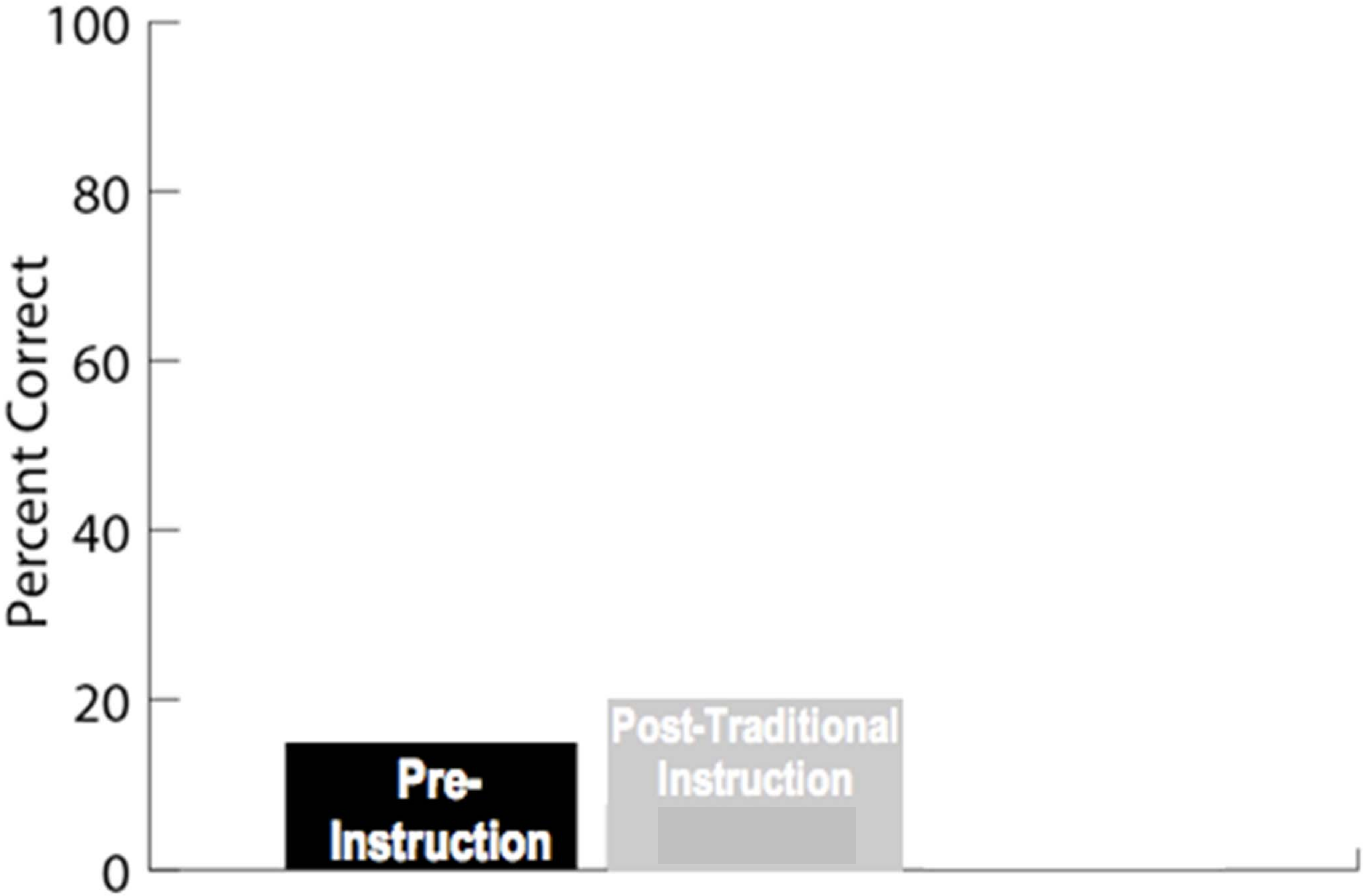

How can they possibly not learn from my perfectly logical, sublimely entertaining lectures!?

The *Force and Motion Conceptual Evaluation (FMCE)*-Research Based Alternative to the *FCI*

- A multiple choice test of student conceptual understandings.
- Described in the pre-workshop article and in much more detail in *American Journal of Physics* paper: **66**, 338-352 (1998).

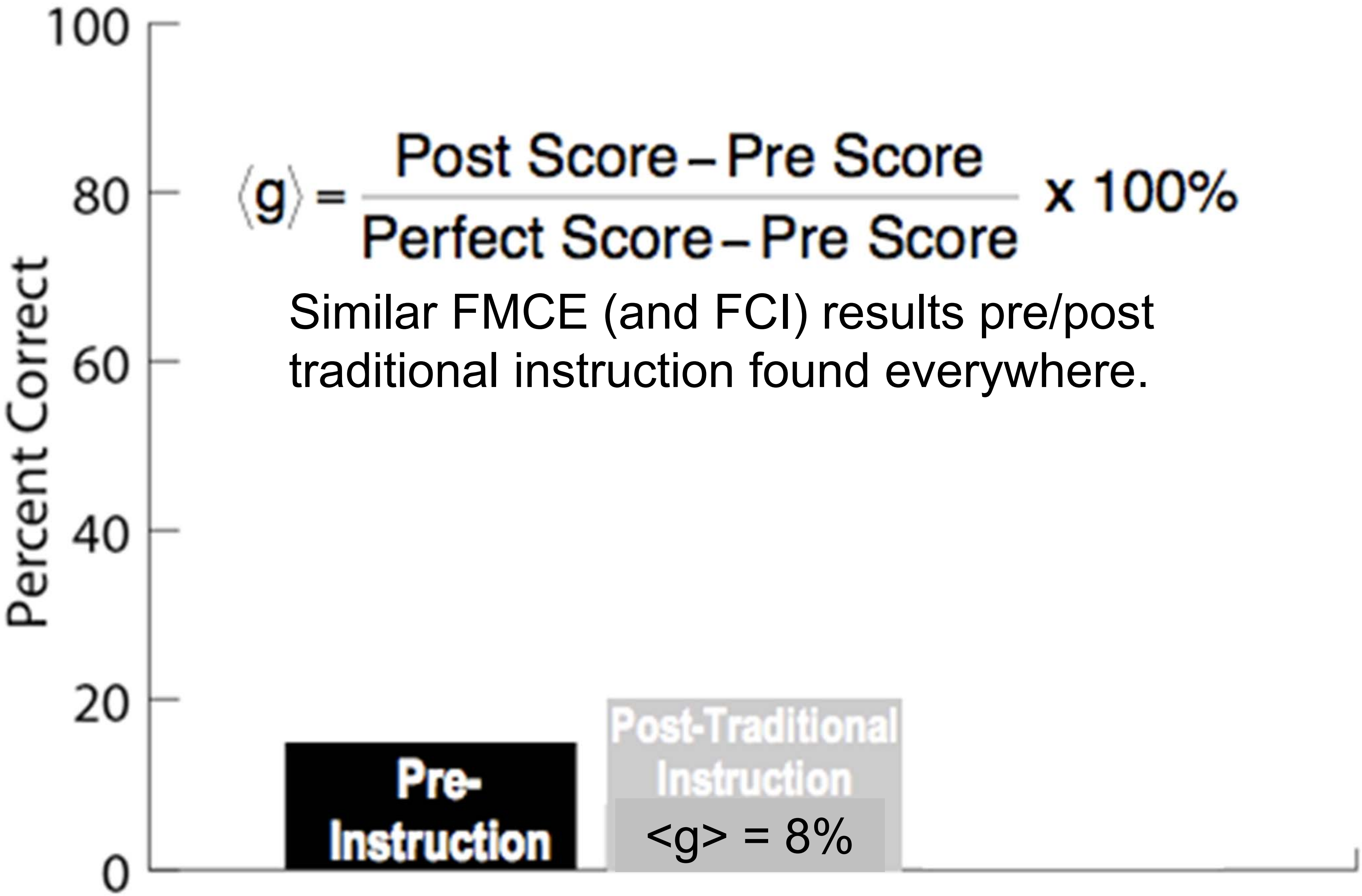
Results for General Physics students at University of Oregon *before active learning was implemented*

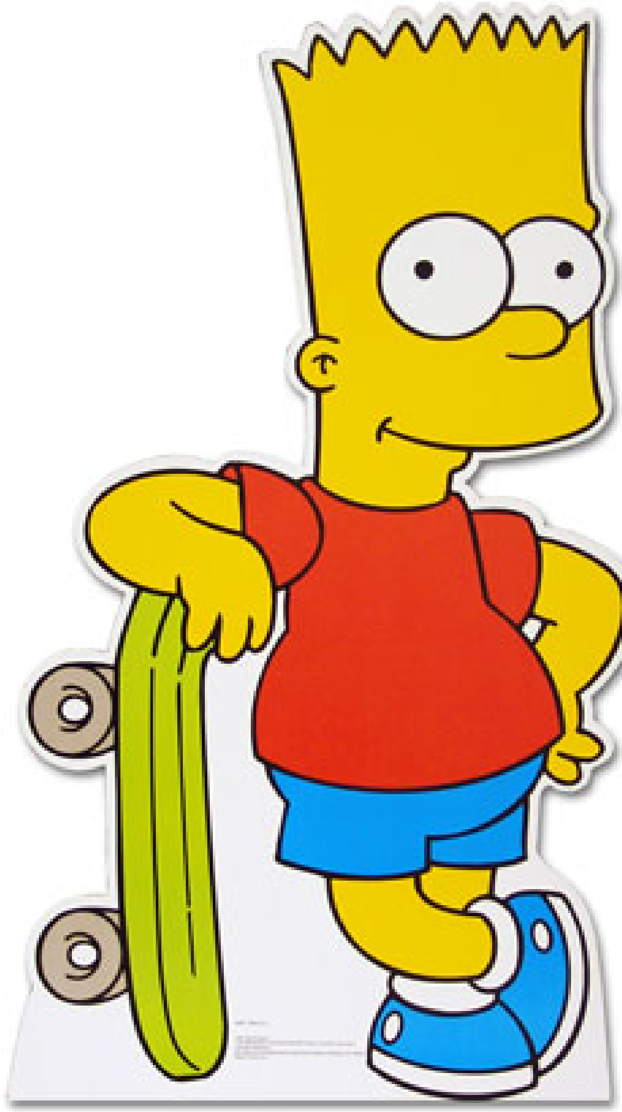


Results for General Physics students at University of Oregon *before active learning was implemented*

$$\langle g \rangle = \frac{\text{Post Score} - \text{Pre Score}}{\text{Perfect Score} - \text{Pre Score}} \times 100\%$$

Similar FMCE (and FCI) results pre/post traditional instruction found everywhere.



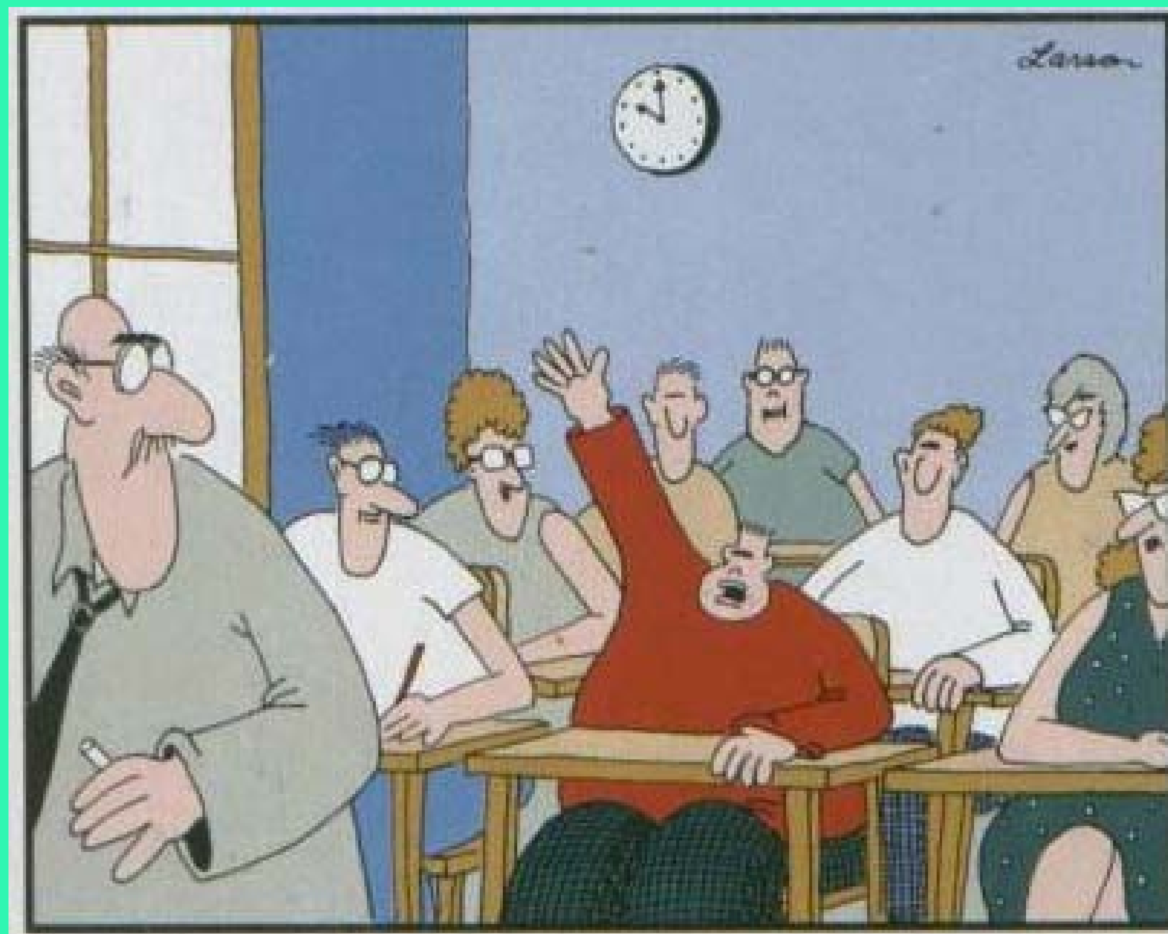


“Underachiever . . .
and proud of it, man!”

The Proposed Solution . . .

Active Learning environments *complementing but not replacing more quantitative work.*

Most students spend the majority of their time in a lecture, often a large one!



"Prof. Sokoloff, may I be excused?
My brain is full!"

Can an active learning environment be created in a large (or small) lecture?

Yes, through the use of

Interactive Lecture Demonstrations (ILDs)

Example of *ILDs*

- You will be our introductory physics class for the next 15 minutes or so.
- We will show you demonstrations and ask you to make predictions on a Prediction Sheet.
- Note that <u>predictions are never graded</u>, but you will receive 1 point out of the 100 points for this class for participating today.
- We will next ask you to discuss your predictions with your nearest neighbor(s), and see if your small group can reach a consensus on the prediction.
- Finally, we will do the demonstrations with the results displayed. We will ask for volunteers to discuss what you observe with the whole class.

Hand in This Sheet **Name**________________________________

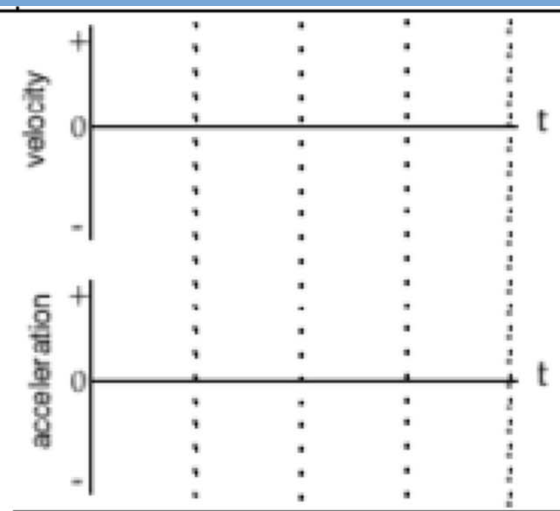
SAMPLE INTERACTIVE LECTURE DEMONSTRATION PREDICTION SHEET

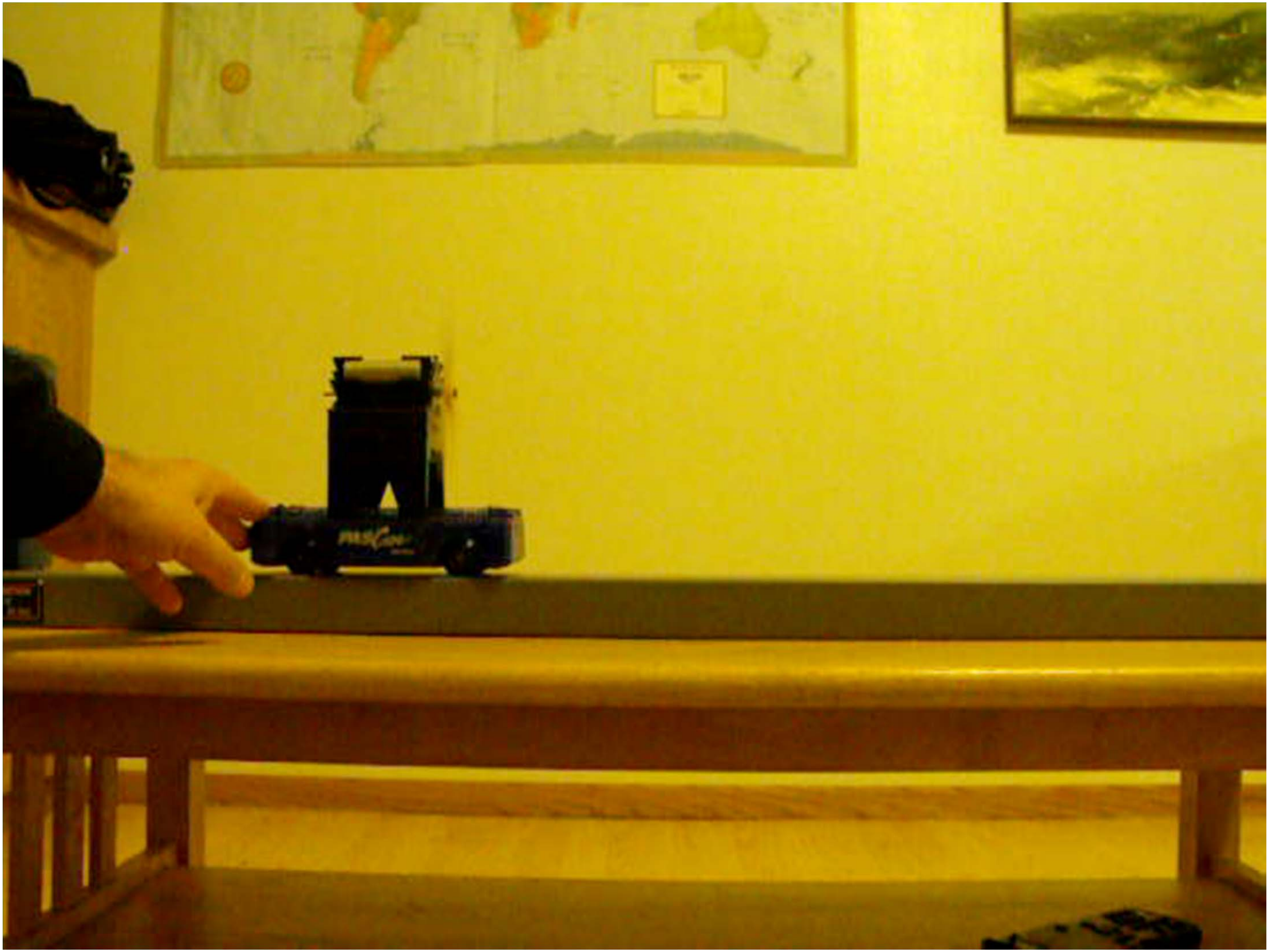
Note: This is a sample of interactive demonstrations. They do not represent a coherent sequence. See the tested sequences of demonstrations in the book, Interactive Lecture Demonstrations, available from Wiley.

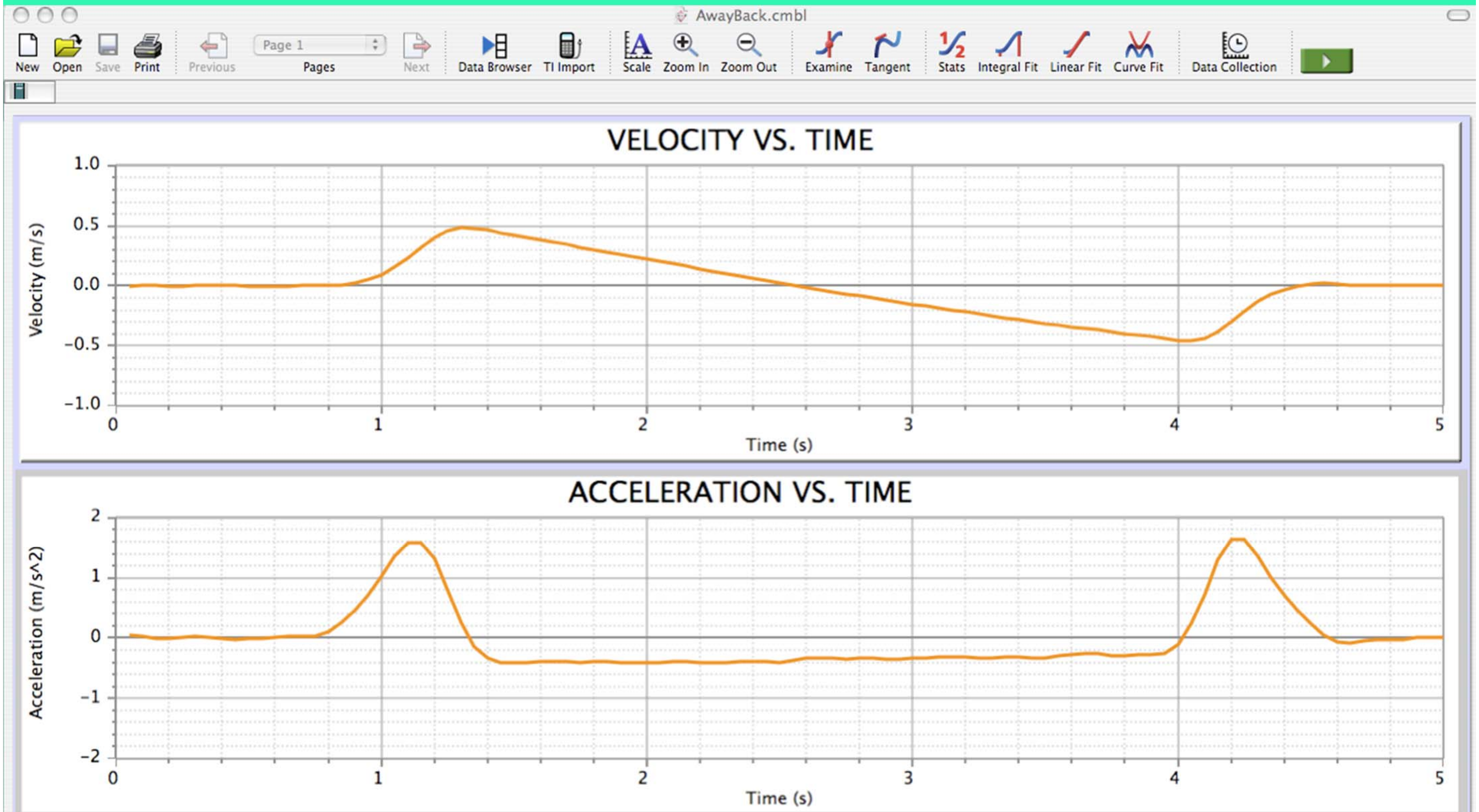
Directions: This sheet will be collected as a record of your attendance and participation. Print your name at the top. You may write anything you like on the attached *Results* sheet and take it with you.

Mechanics Demonstration 2:

The origin of the coordinate system is on the floor, and the positive direction is upward. The ball is thrown, moves upward, slowing down, reaches its highest point and falls back downward speeding up as it falls. Sketch on the axes on the right your predictions for the velocity-time and acceleration-time graphs of the ball from the moment just after it is released until the moment just before it is hits the floor.







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Time (s)
ACCELERATION VS. TIME
Acceleration (m/s^2)
2
1
0
−1
−2
0
1
2
3
4
5
Time (s)

Hand in This Sheet **Name**______________________________

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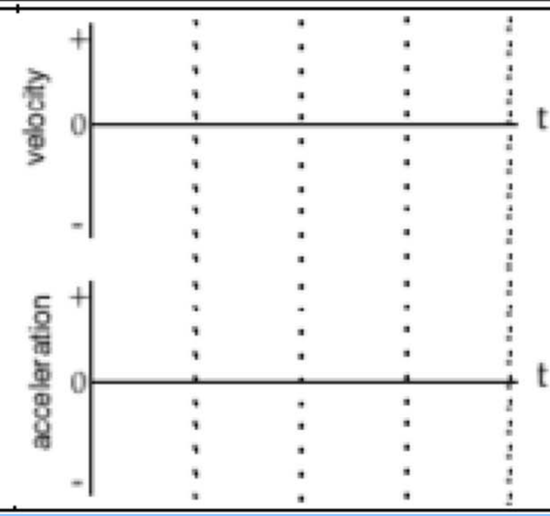
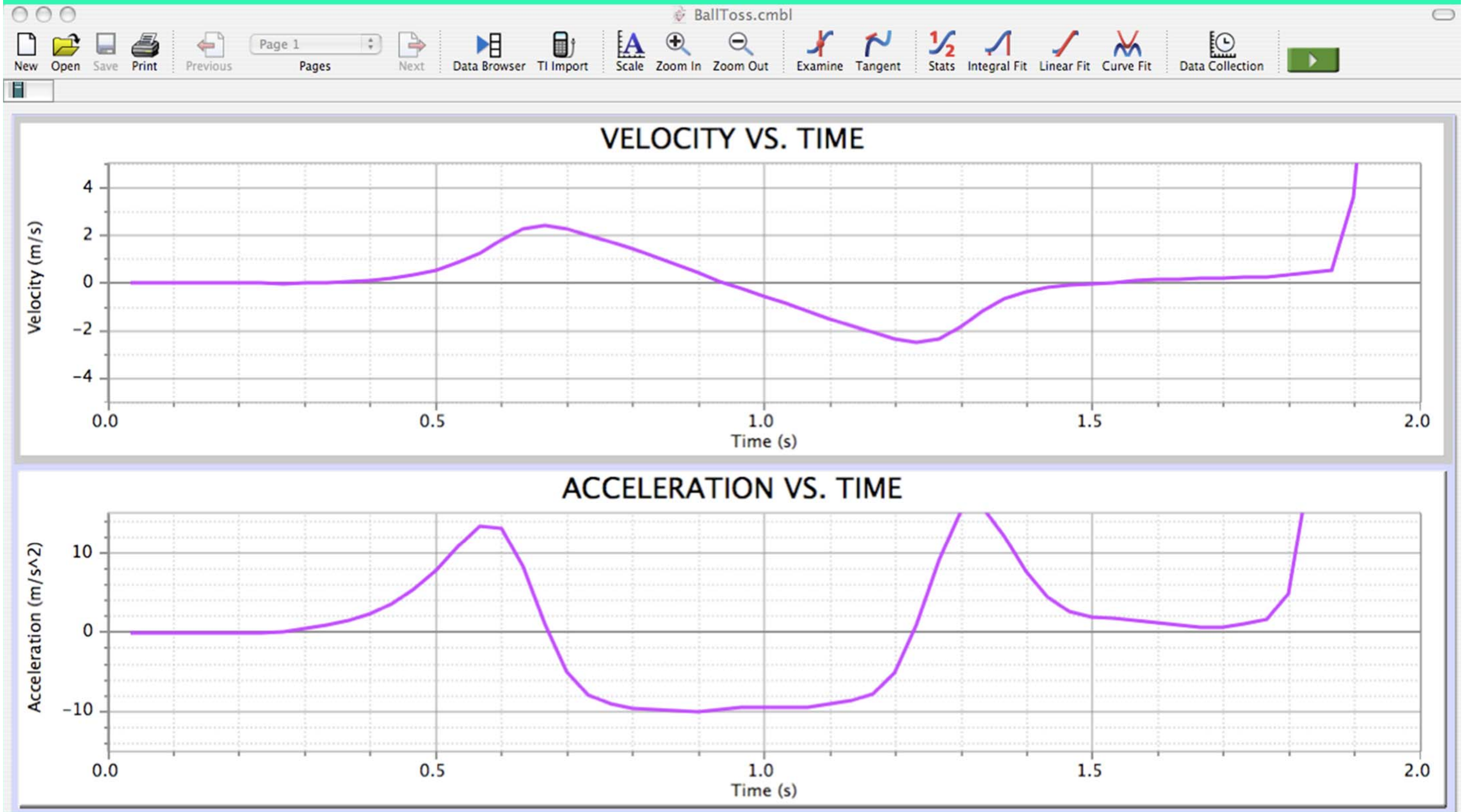
Mechanics Demonstration 1:

A cart is subjected to a constant force in the direction towards the motion detector. Sketch on the axes on the right your predictions of the velocity and acceleration of the cart after it is given a short push away from the motion detector (and is released). Sketch velocity and acceleration as the cart slows down moving away from the detector, comes *momentarily* to rest and then speeds up moving towards the detector.




Motion sensor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VELOCITY VS. TIME
Velocity (m/s)
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1.5
2.0
Time (s)
ACCELERATION VS. TIME
Acceleration (m/s^2)
10
0
-10
0.0
0.5
1.0
1.5
2.0
Time (s)

Interactive Lecture Demonstrations (ILDs)

1. Describe the demonstration and do it for the class without results displayed.
2. Ask students to record individual predictions on the Prediction Sheet.
3. Have the class engage in small group discussions.
4. Elicit common student predictions from the whole class.
5. Students record final prediction on the Prediction Sheet (which will be collected).
6. Carry out the demonstration and display the results.
7. Ask a few students to describe the results and discuss them in the context of the demonstration. Students may fill out the Results Sheet.
8. If appropriate, discuss analogous physical situations with different "surface" features.

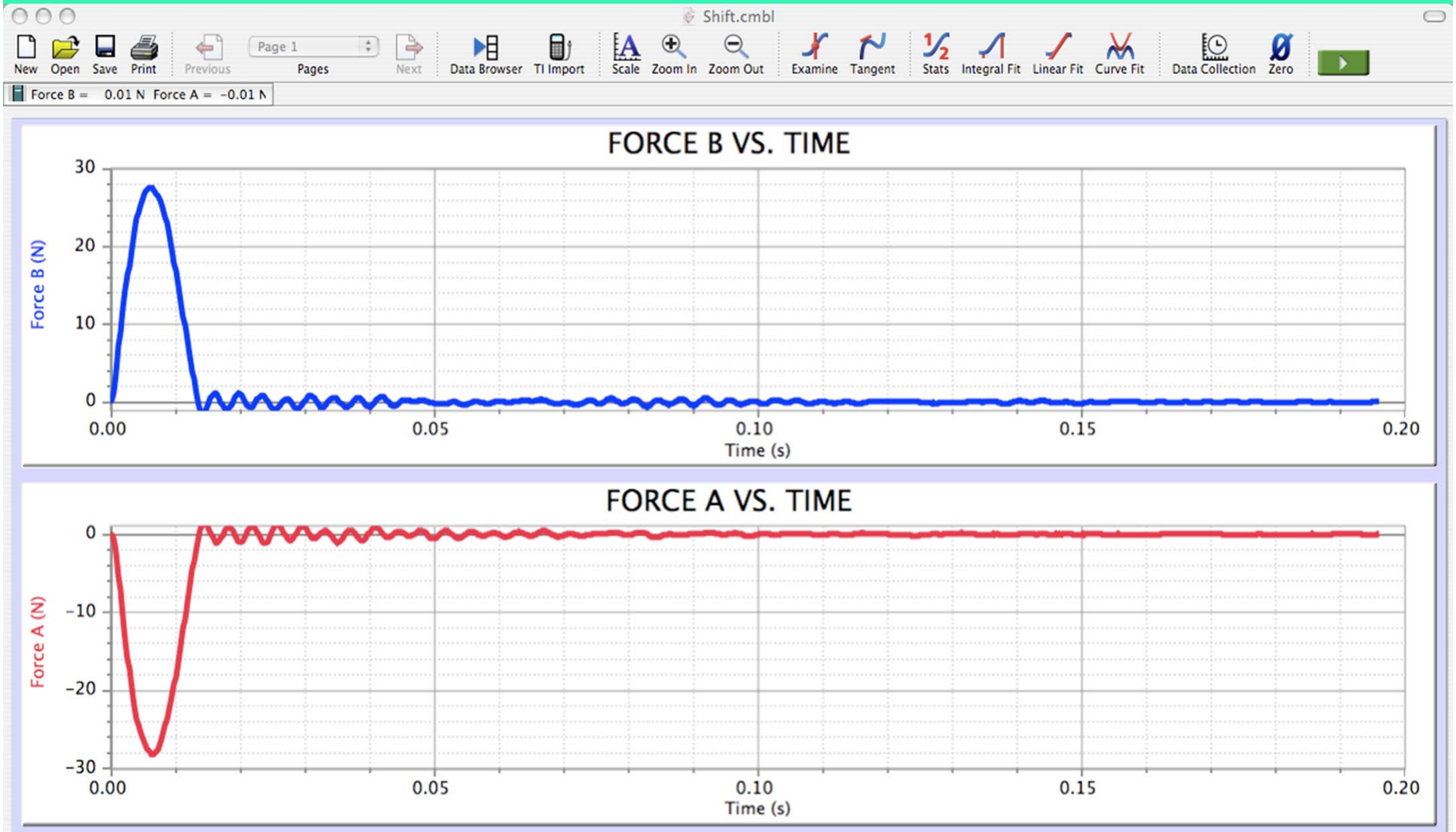
This procedure is followed for each of the short lecture demonstrations in each *ILD* sequence.

Characteristics of Active Learning Environments

- The physical world is the authority for knowledge. Instructor’s role is as a guide.
- Incorporates a learning cycle: prediction/ observation/comparison. Challenges students’ beliefs.
- Collaboration and shared learning with peers is encouraged.
- Results from real experiments are observed in understandable ways—often in real time with computer-based tools.
- Laboratory work is used to learn basic concepts.

Another Mechanics *ILD* Example


Heavy Cart A
Light Cart B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FORCE B VS. TIME
Force B (N)
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Time (s)
FORCE A VS. TIME
Force A (N)
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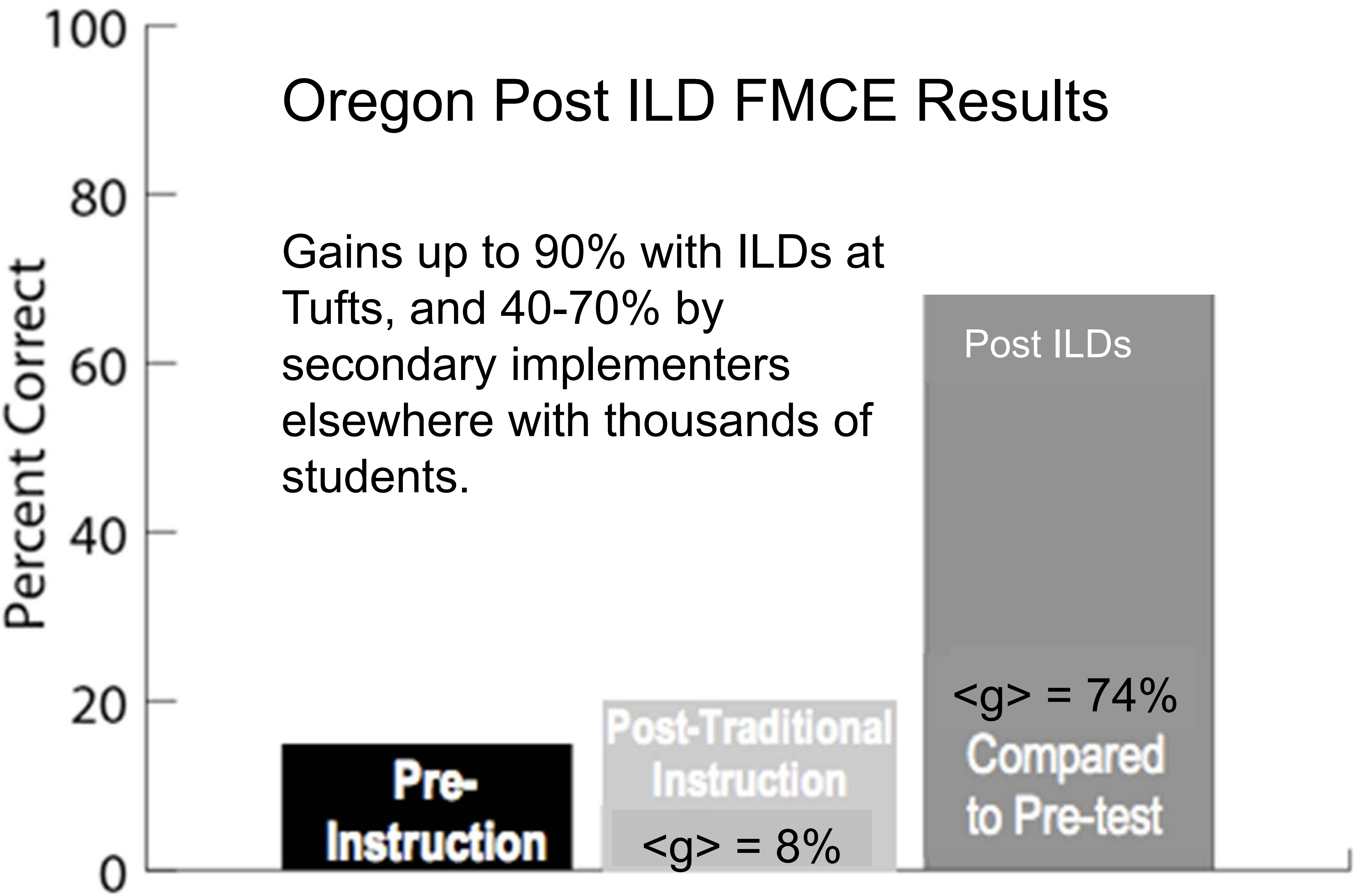
-10
-20
-30
0.00
0.05
0.10
0.15
0.20
Time (s)

Do students learn concepts from *ILDs*?

Oregon Post ILD FMCE Results

Gains up to 90% with ILDs at Tufts, and 40-70% by secondary implementers elsewhere with thousands of students.



Do Students Learn from Traditional Demonstrations?

NO!

Research from Mazur’s PER group at Harvard has shown that the majority of students who are not asked to make a prediction before a demonstration is done, are not able to describe the outcome of the demonstration correctly, let alone learn from it!

Characteristics of the Curricula that Make Them Effective

- Making predictions requires students to consider their beliefs before making observations of the physical world. The *ILDs* build upon the knowledge that students bring into the course.
- With *ILDs*, the process of prediction, defending the prediction in a small group, and writing down the prediction engages students. They want to know the result of the demonstration.
- The disequilibrium set up by the difference between prediction and observation inspires effective learning opportunities.
- Student knowledge is constructed from observations of the physical world, thus building students' confidence as scientists.

Choosing *ILD* Experiments

- Simple, single concept experiments that build on each other.
- Students must trust the apparatus and the results.
- Many of our most treasured lecture demonstrations are too complex for much learning to result. They could be broken down into smaller pieces, and presented as *ILDs*.

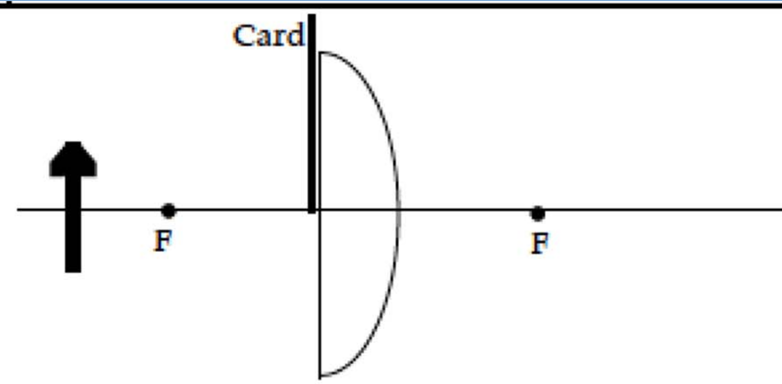
Modes of *ILD* Use

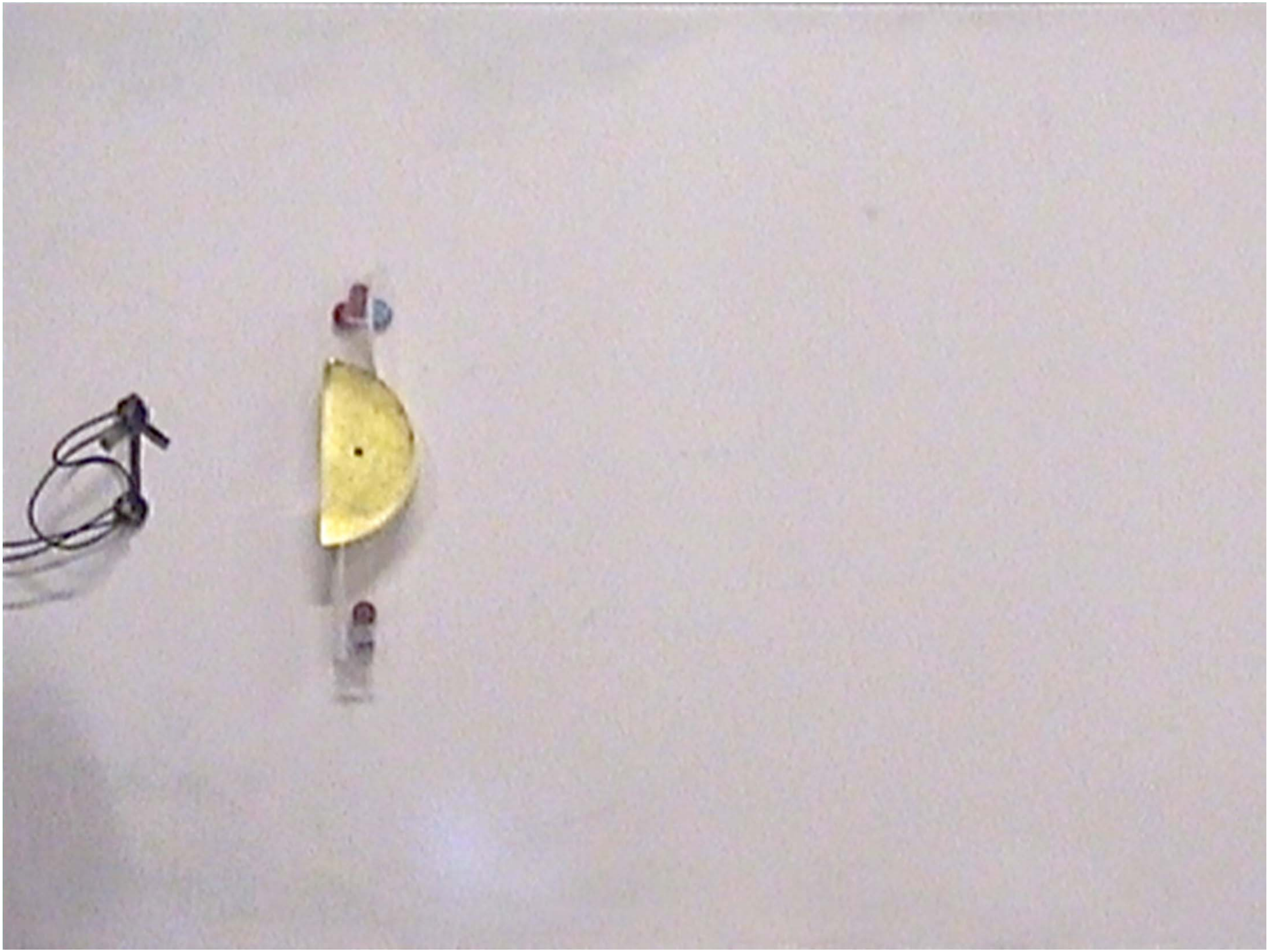
- Introduction of concepts.
- Review or clarification of concepts.
- Activities in a flipped classroom.
- In place of or in conjunction with lab activities.

Example of Low-Tech *ILDs* on Image Formation

- Research evidence shows that students don't understand that an infinite number of rays emanate from each point on an object, and that for a perfect lens, all rays from a single point that are incident on the lens will be focused to a corresponding point on the image.
- In these *ILDs*, two small light bulbs are used as two discrete object point sources of light.

<u>Image Formation Demonstration 2:</u> What will happen to the image if you block the top half of the lens with a card? Answer in words and show what happens on the diagram on the right by making any changes needed in the rays you drew above.





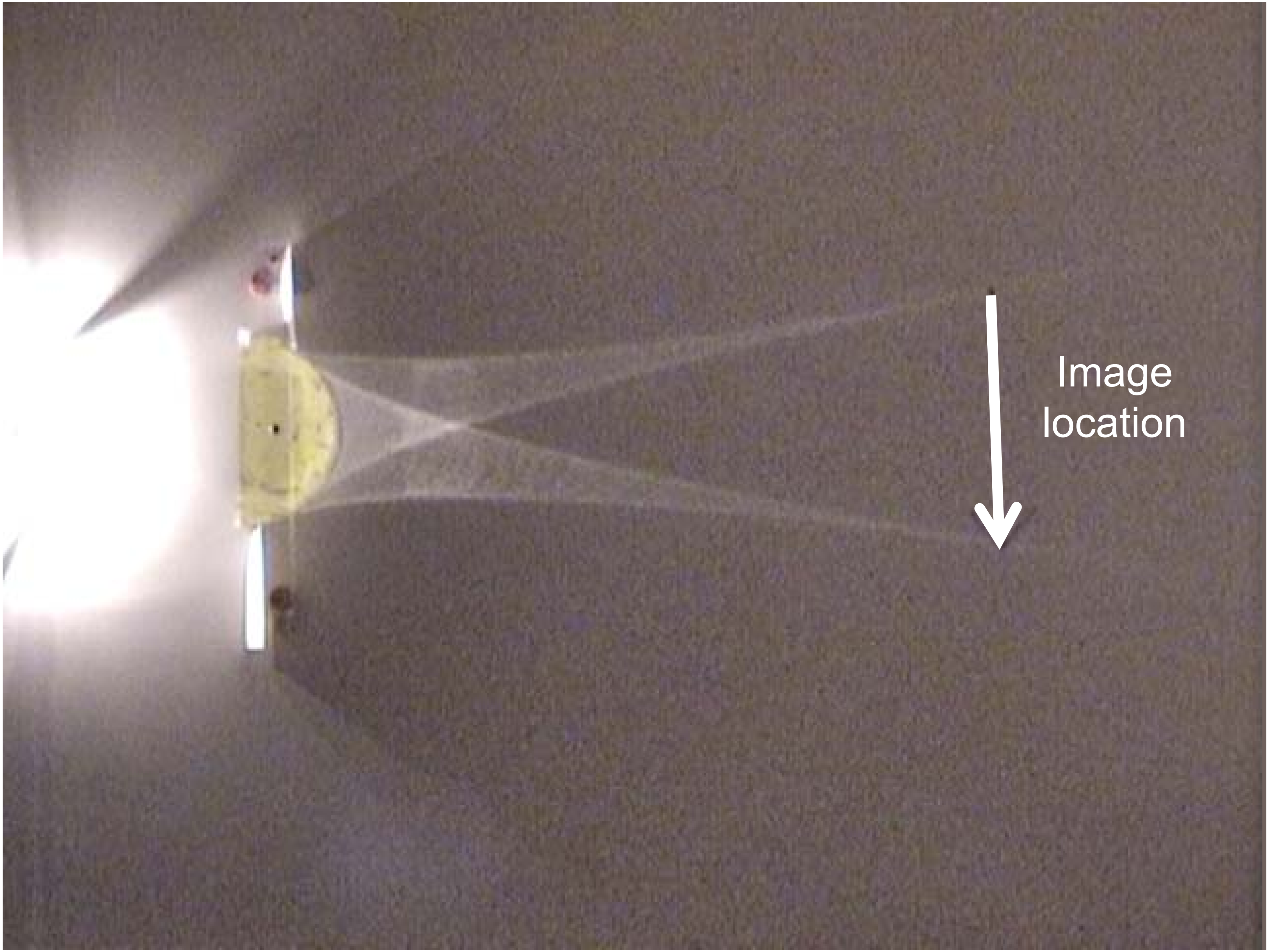
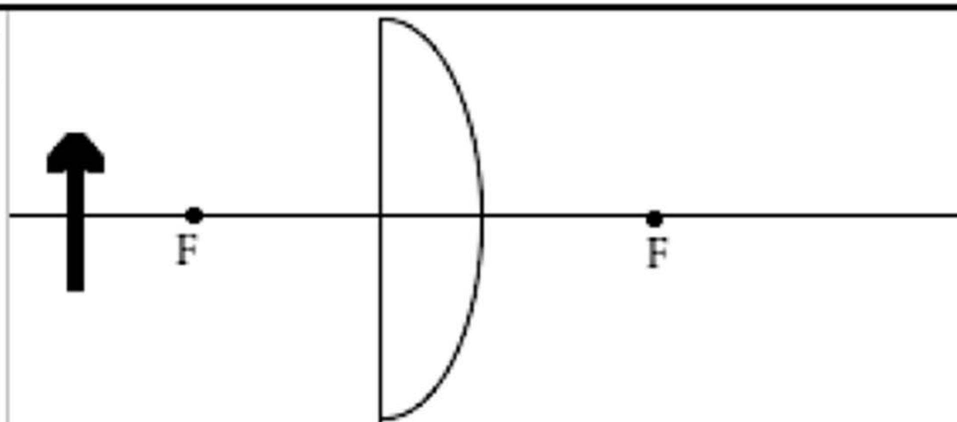


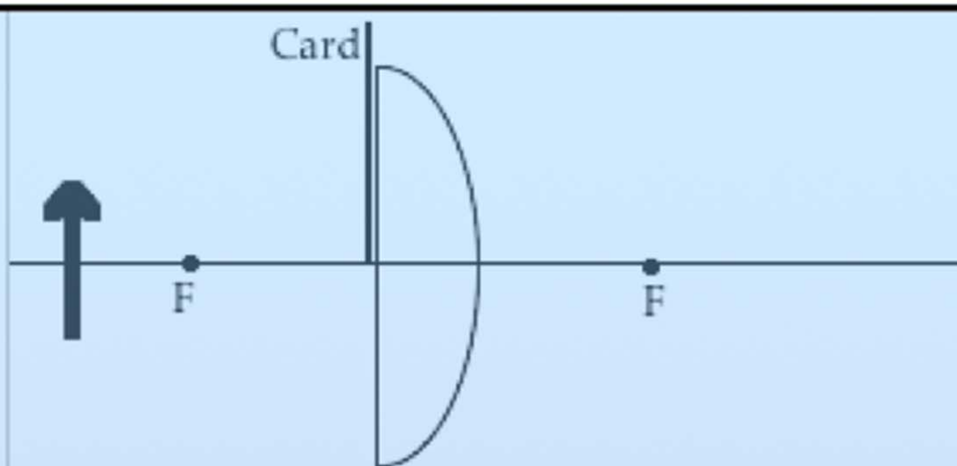
Image
location

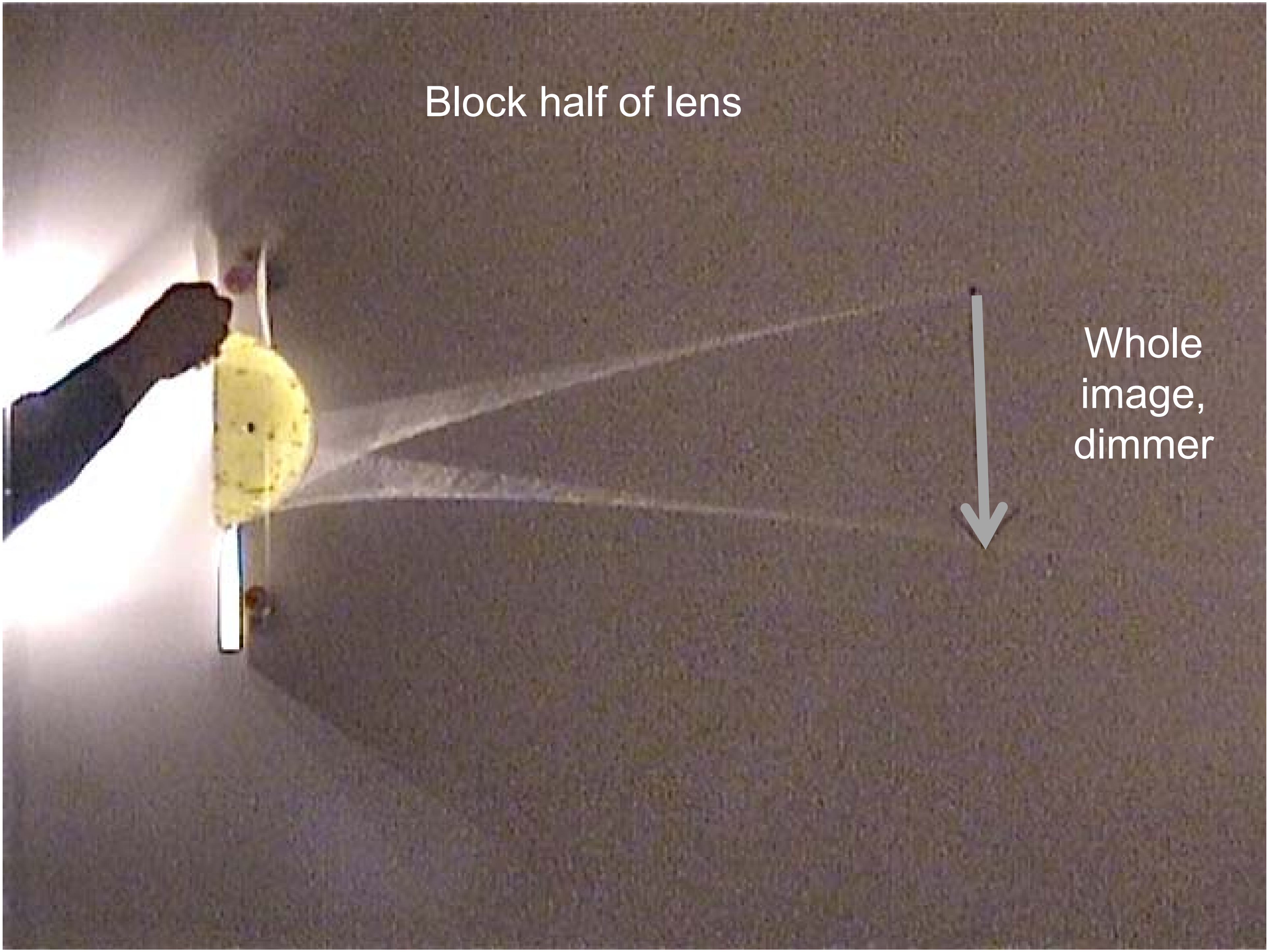
Demonstration 1: You have a converging lens. An object in the shape of an arrow is positioned a distance larger than the focal length to the left of the lens, as shown in the diagram on the right. Draw several rays from the head of the arrow and several rays from the foot of the arrow to show how the image of the arrow is formed by the lens.

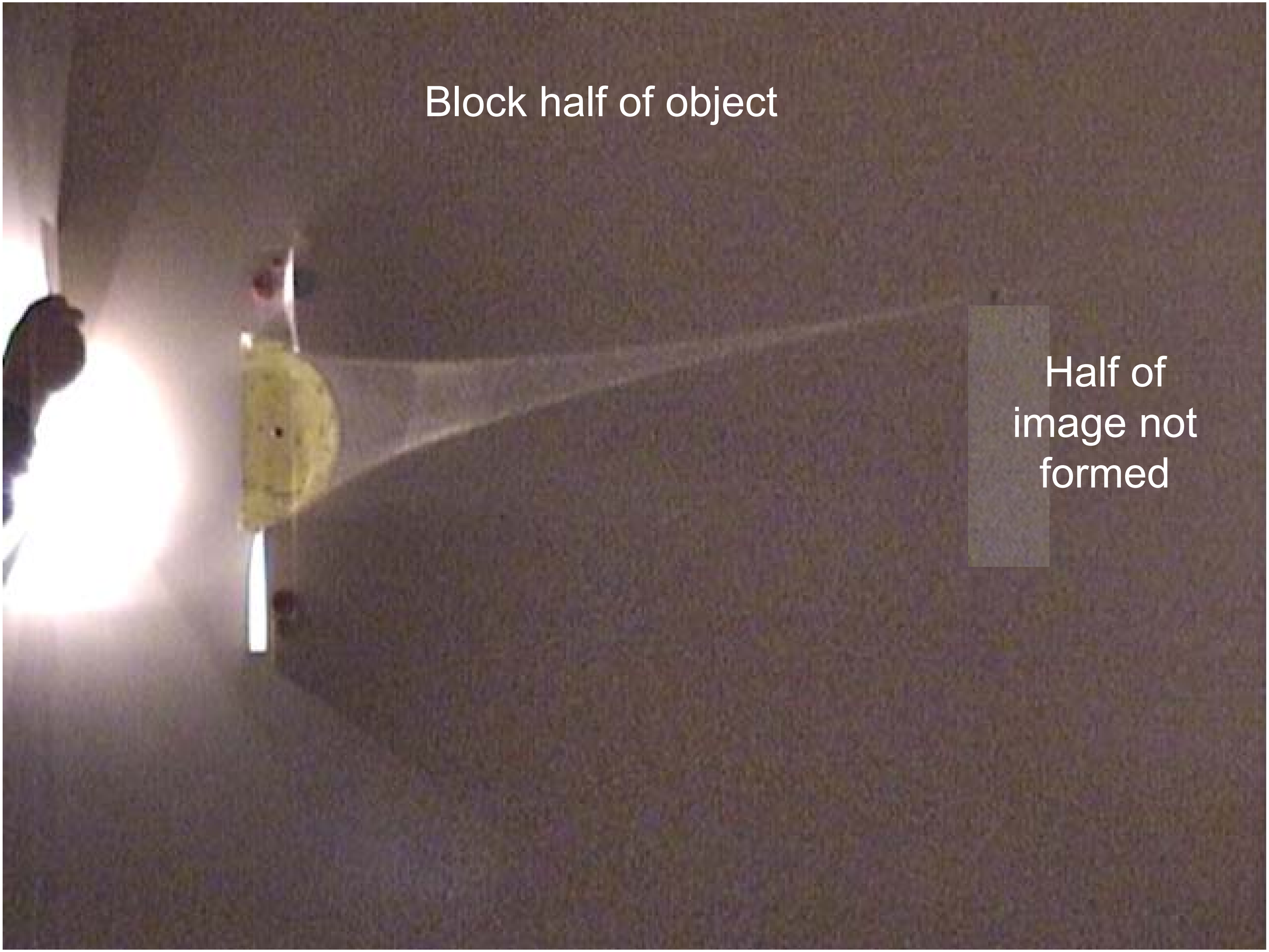
Is this a real or a virtual image?



Demonstration 2: What will happen to the image if you block the top half of the *lens* with a card? Answer in words and show what happens on the diagram on the right by making any changes needed in the rays you drew in Demonstration 1.




Block half of lens
Whole
image,
dimmer

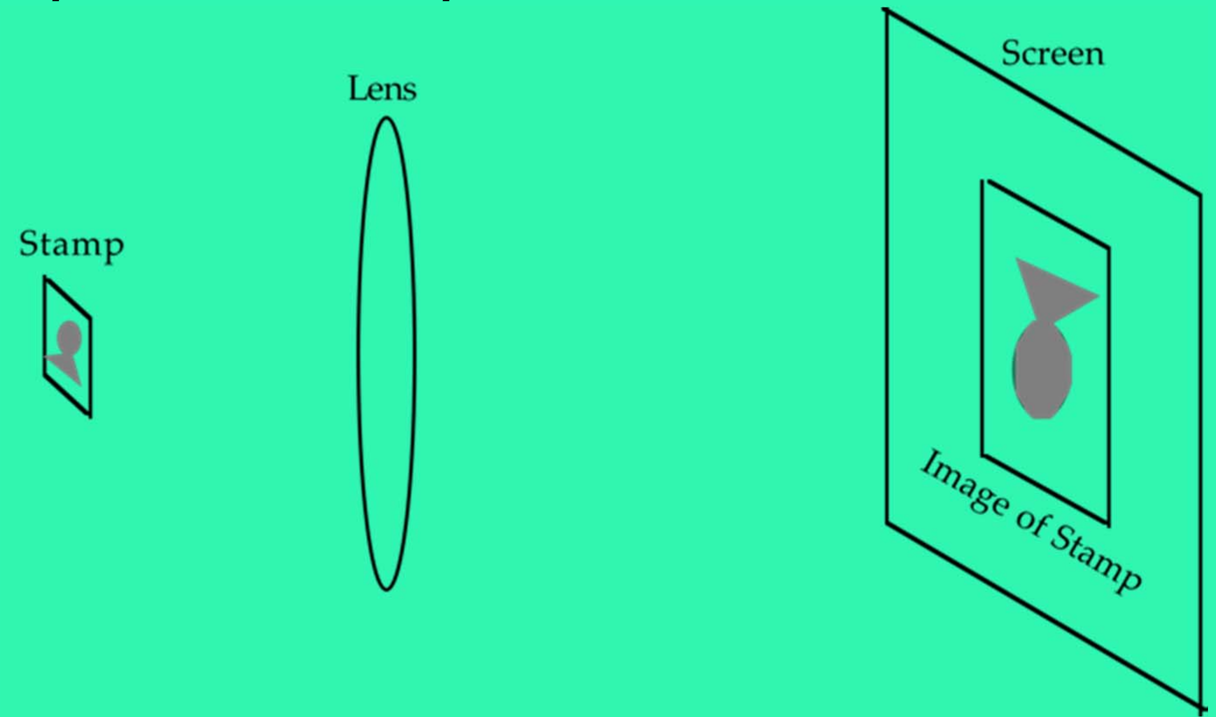

Block half of object
Half of
image not
formed

Do students learn from the Image Formation *ILDs*?

Image Formation Questions from the *Light and Optics Conceptual Evaluation*

Questions 1-6 refer to the picture on the right. A stamp is placed to the left of the lens, and its image is formed on a screen to the right of the lens, as shown.

Choose the correct answer for each question.



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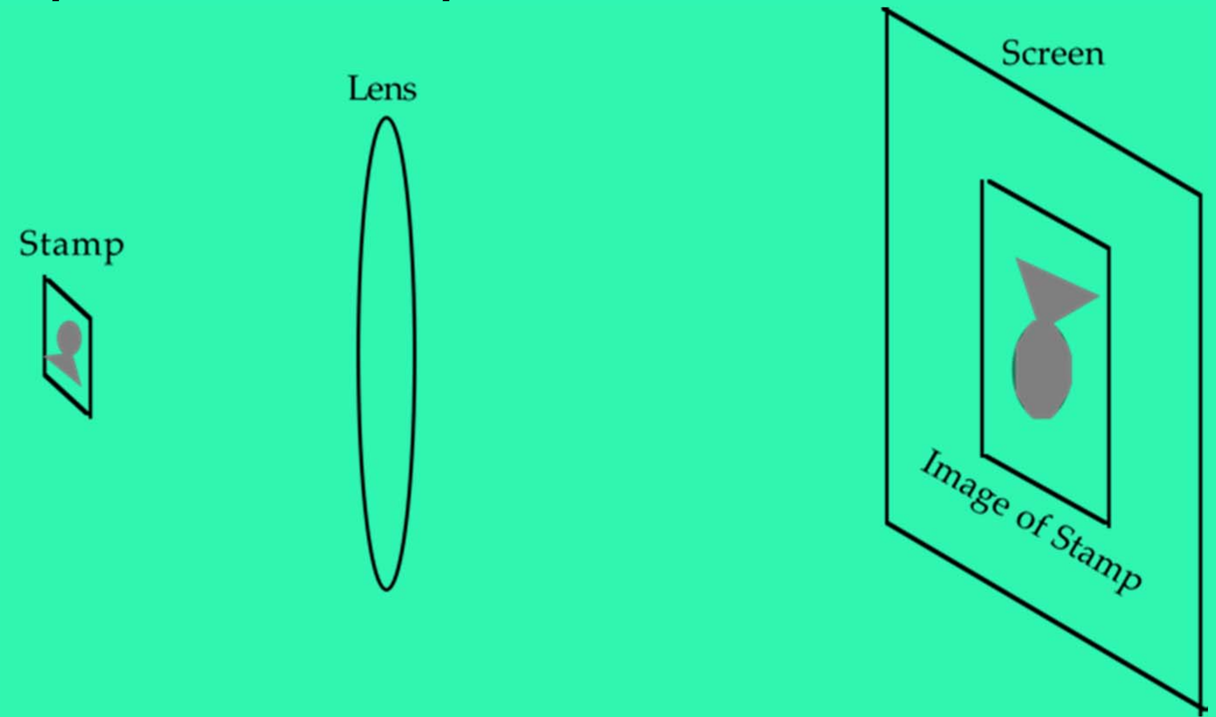
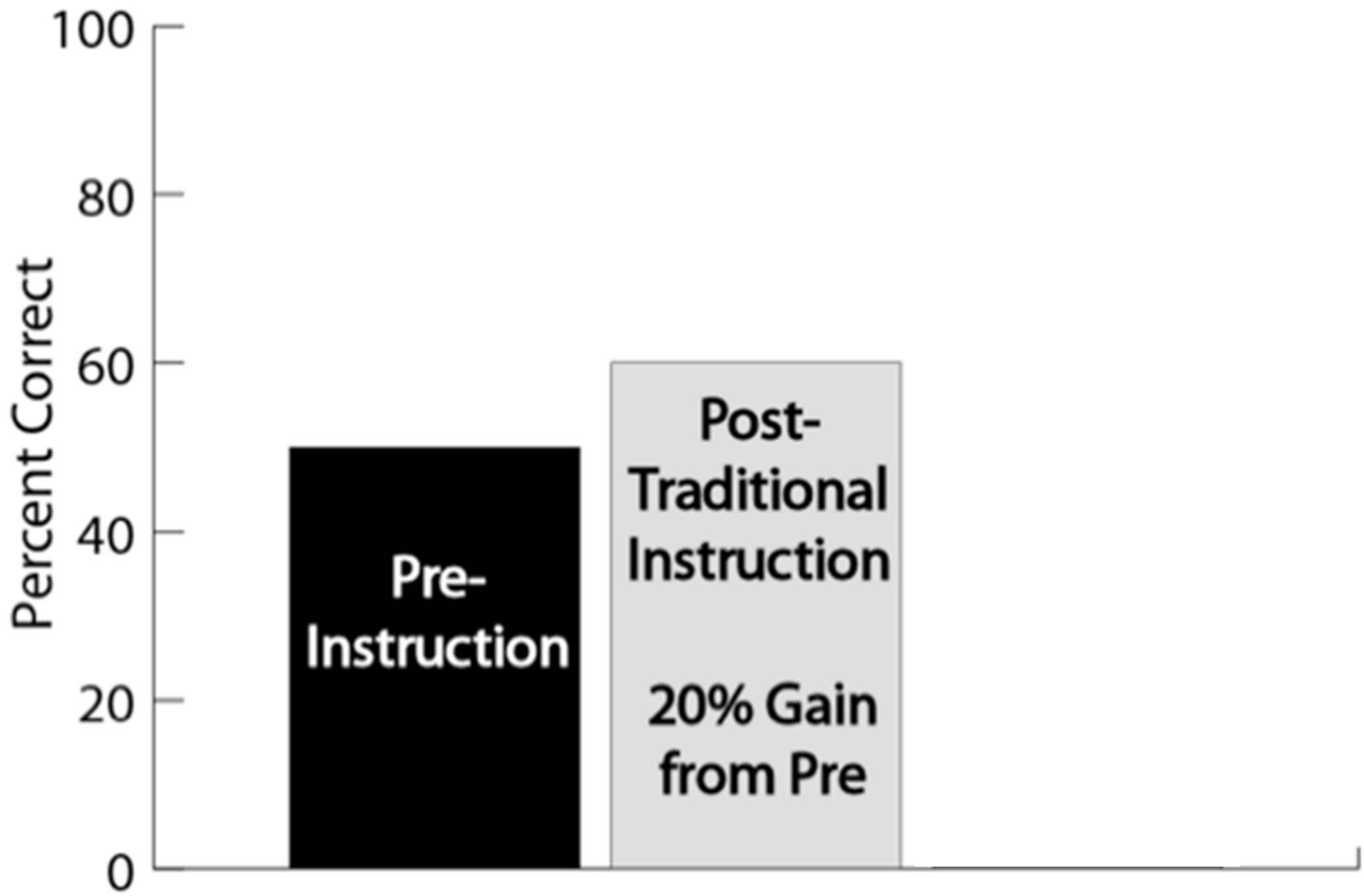


Questions ask what will happen to the image if changes are made, e.g., block half the lens, block half the object, remove the lens . . .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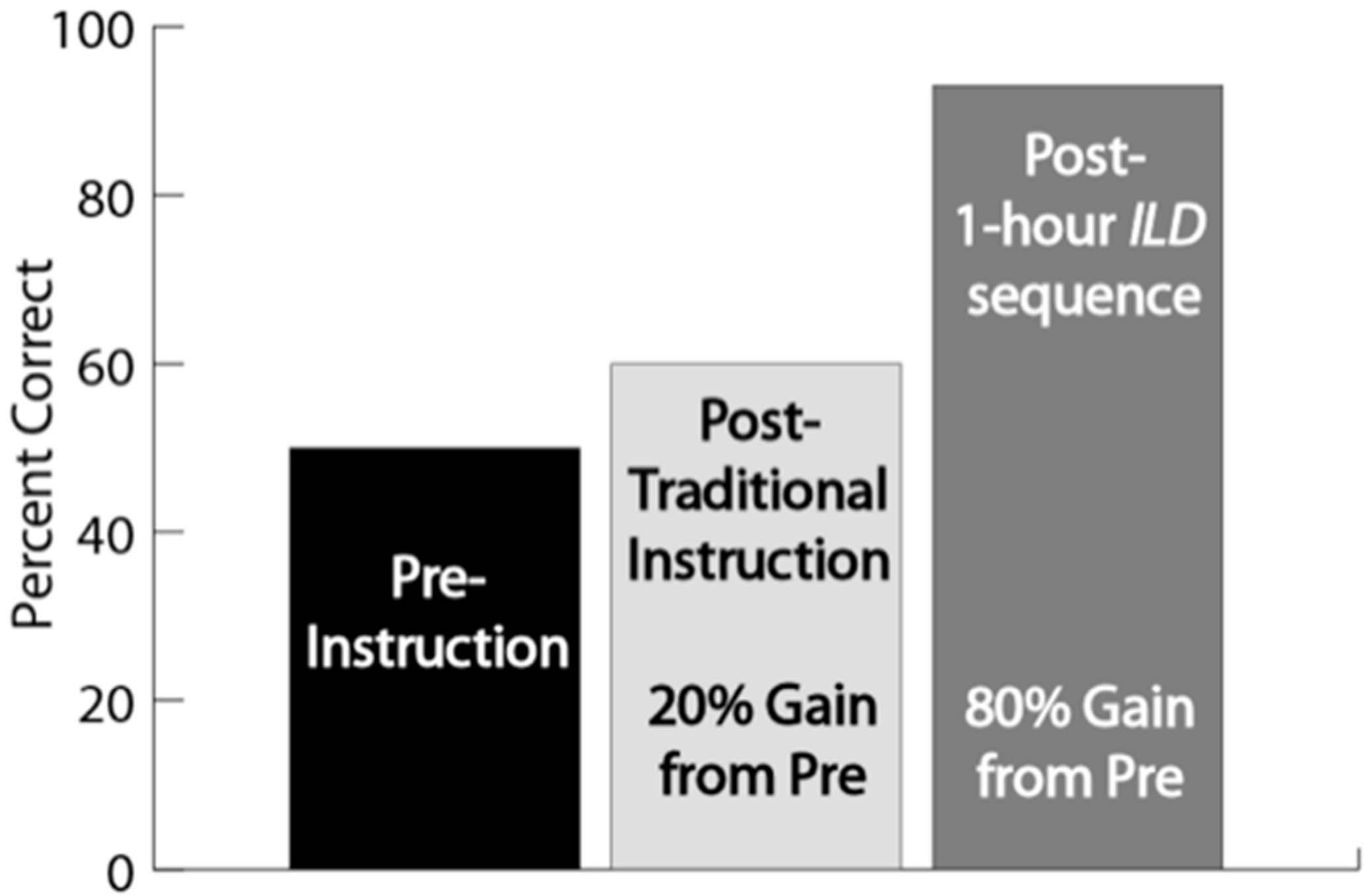
100
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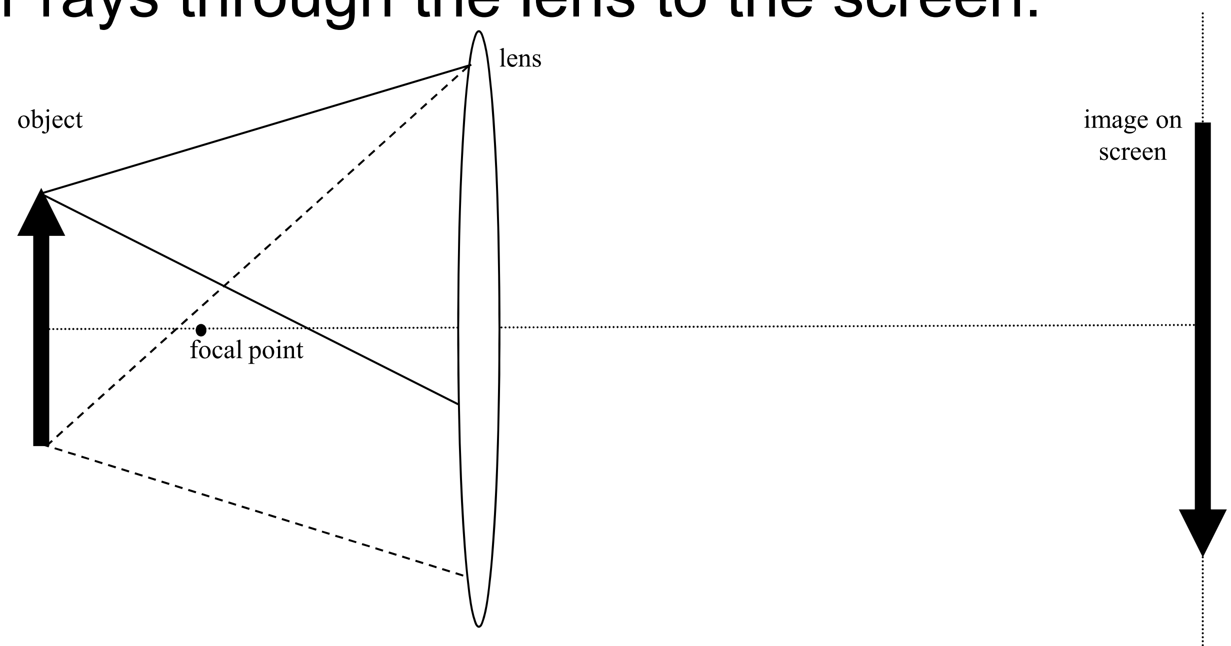
Percent Correct
Pre-
Instruction
Post-
Traditional
Instruction
20% Gain
from Pre
Post-
1-hour *ILD*
sequence
80% Gain
from Pre

51. In the picture below, the object is to the left of the lens, at a distance from the lens that is larger than the focal length. The image is formed on a screen to the right of the lens as shown. Four rays of light are shown leaving points on the object. Continue those four rays through the lens to the screen.



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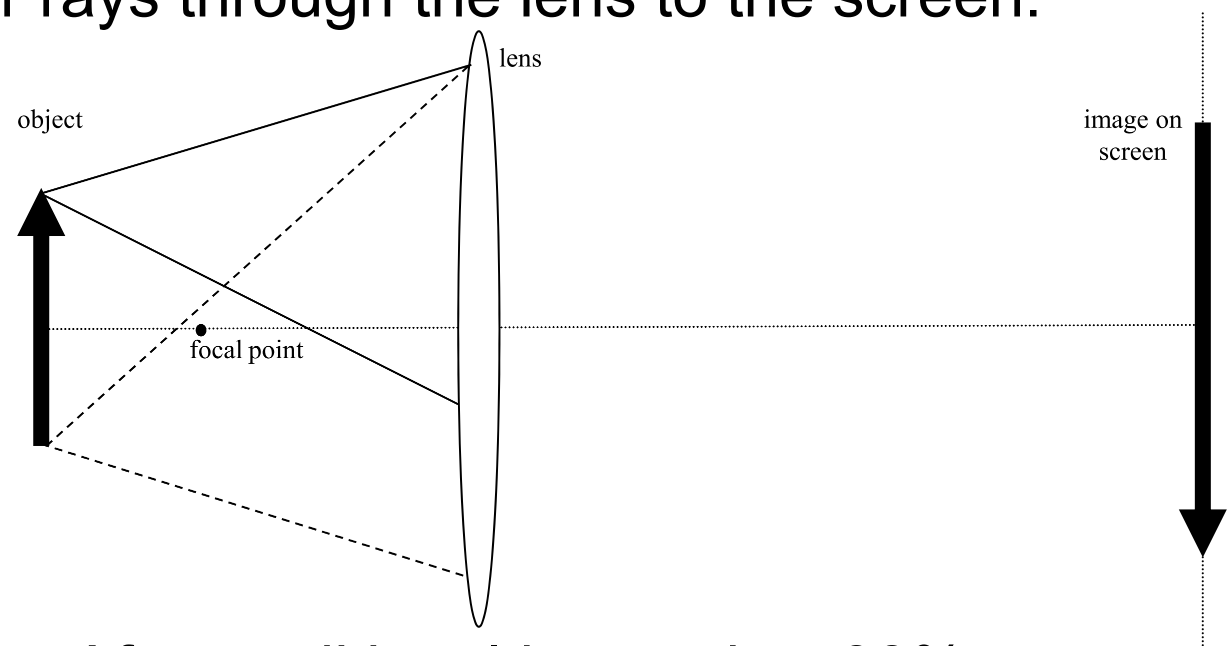

After traditional instruction: 33% correct

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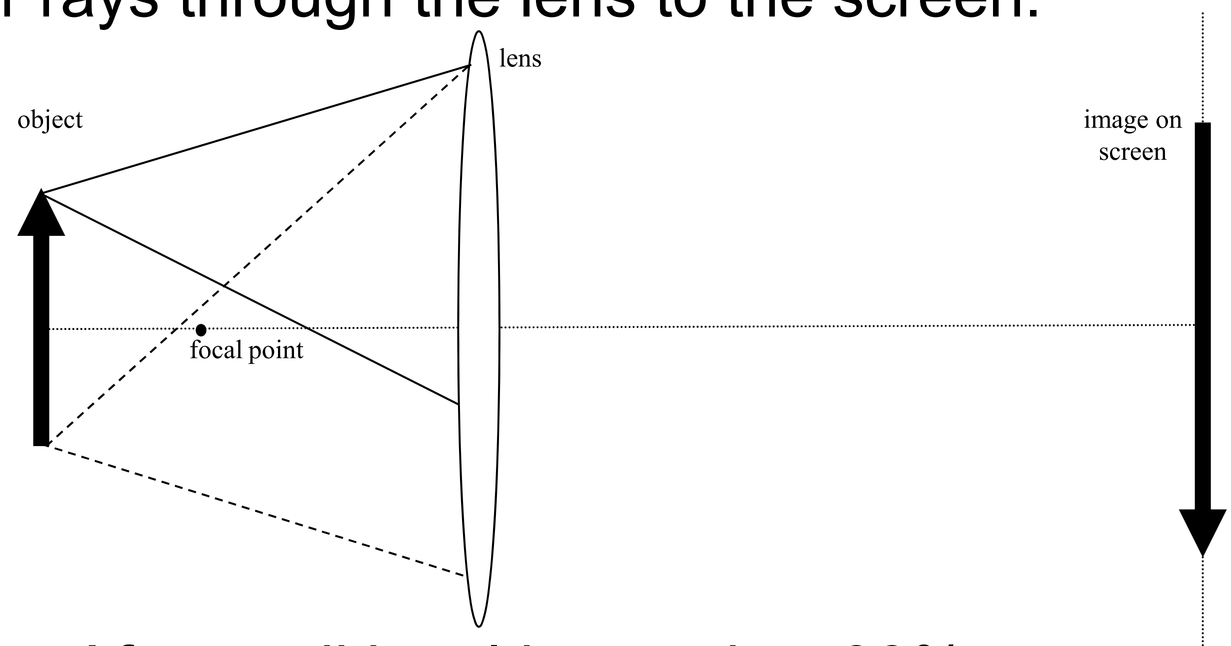


After traditional instruction: 33% correct

After *ILDs*: 76% correct

THE ENTIRE BOOK IS ON YOUR FLASH DRIVE. You can also get a free, paper copy from your Wiley rep.

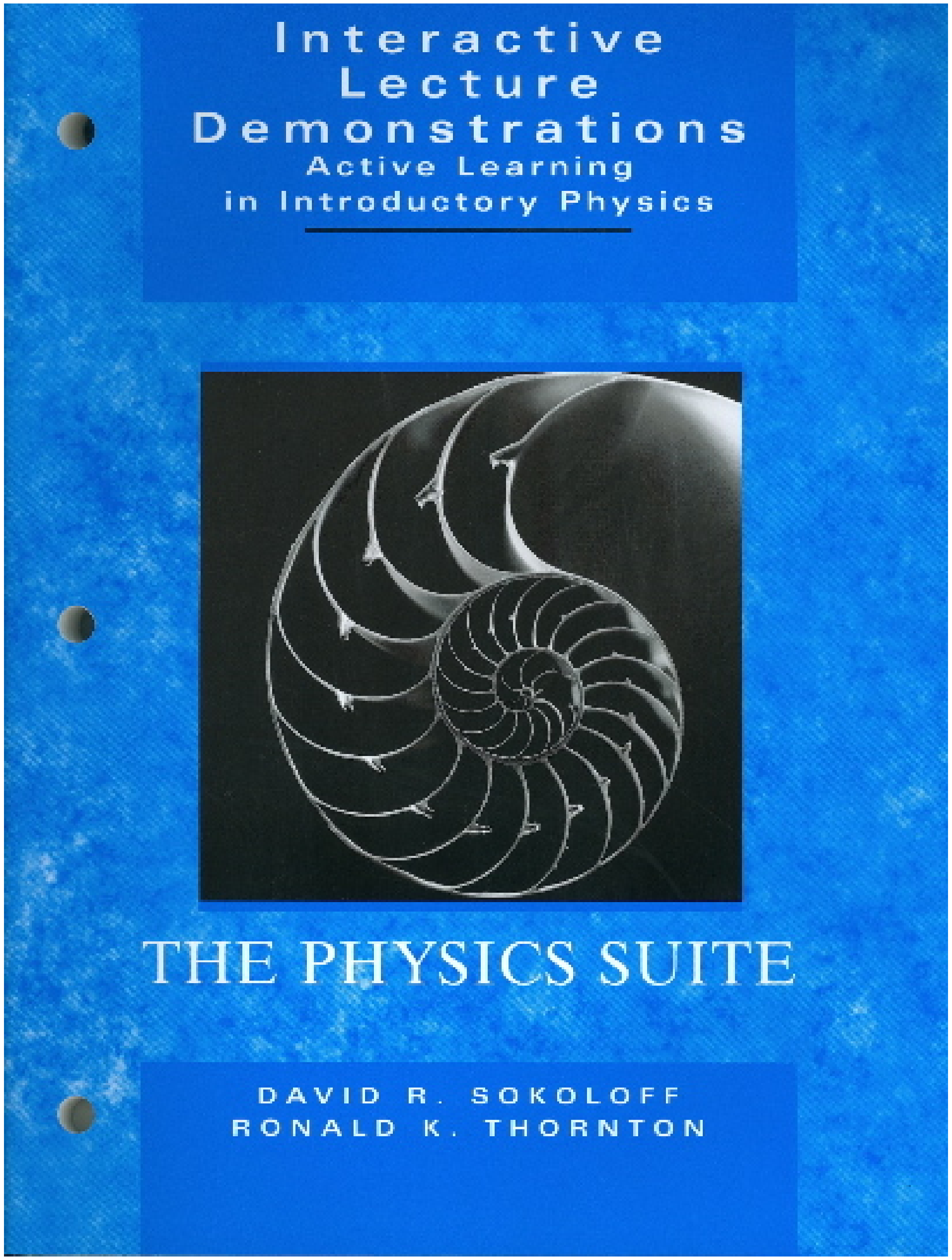
Contains everything you need to do *ILDs* on 28 different topics:

Student Prediction and Results Sheets which can be copied for students

Instructor's Guide for each set of *ILDs*

Teacher Preparation Notes

8-Step Process . . .
suitable for framing



Some Additional Important Notes

- Note, two people are not needed to present *ILDs!*
- *ILDs* are easily implemented, require just one set of equipment, are often the start to incremental changes.
- But there are some serious potential pitfalls.
- Don’t switch to lecturing after the results are displayed—it won’t work. Discussion must come from students!
- Don’t focus on minute details of the results or apparatus—the desired conceptual learning will get lost in these details.
- Take some time at the beginning of the course to explain why you are using this pedagogy. What is the evidence that learning will be more effective?

A Few Words About Active Learning in the Introductory Lab

The focus of this presentation has been on strategies for lecture.

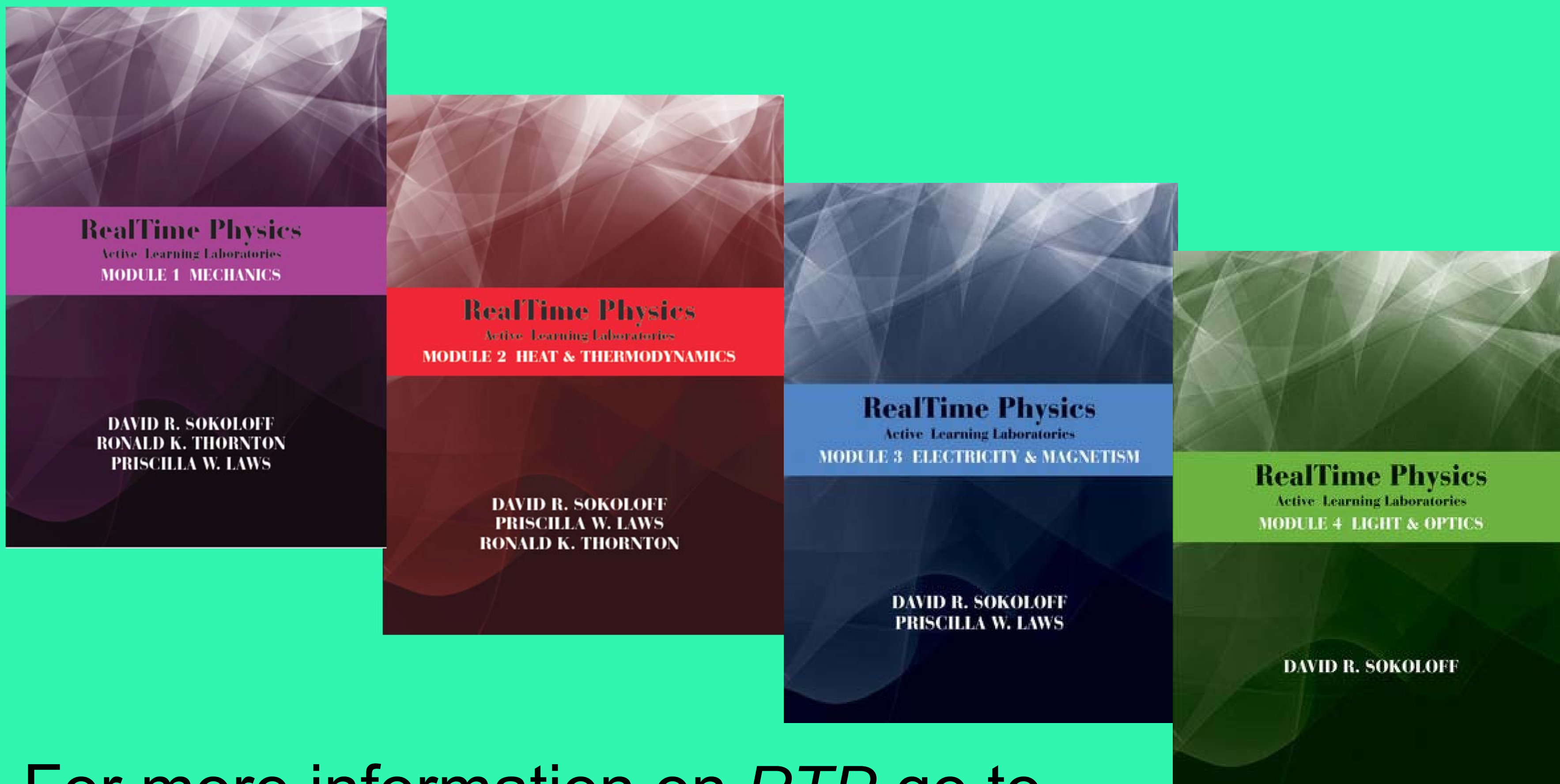
RealTime Physics (RTP) labs promote active learning in the intro. laboratory with real observations of the physical world, often aided by computer-based tools.

They use the same learning cycle as *ILDs*.

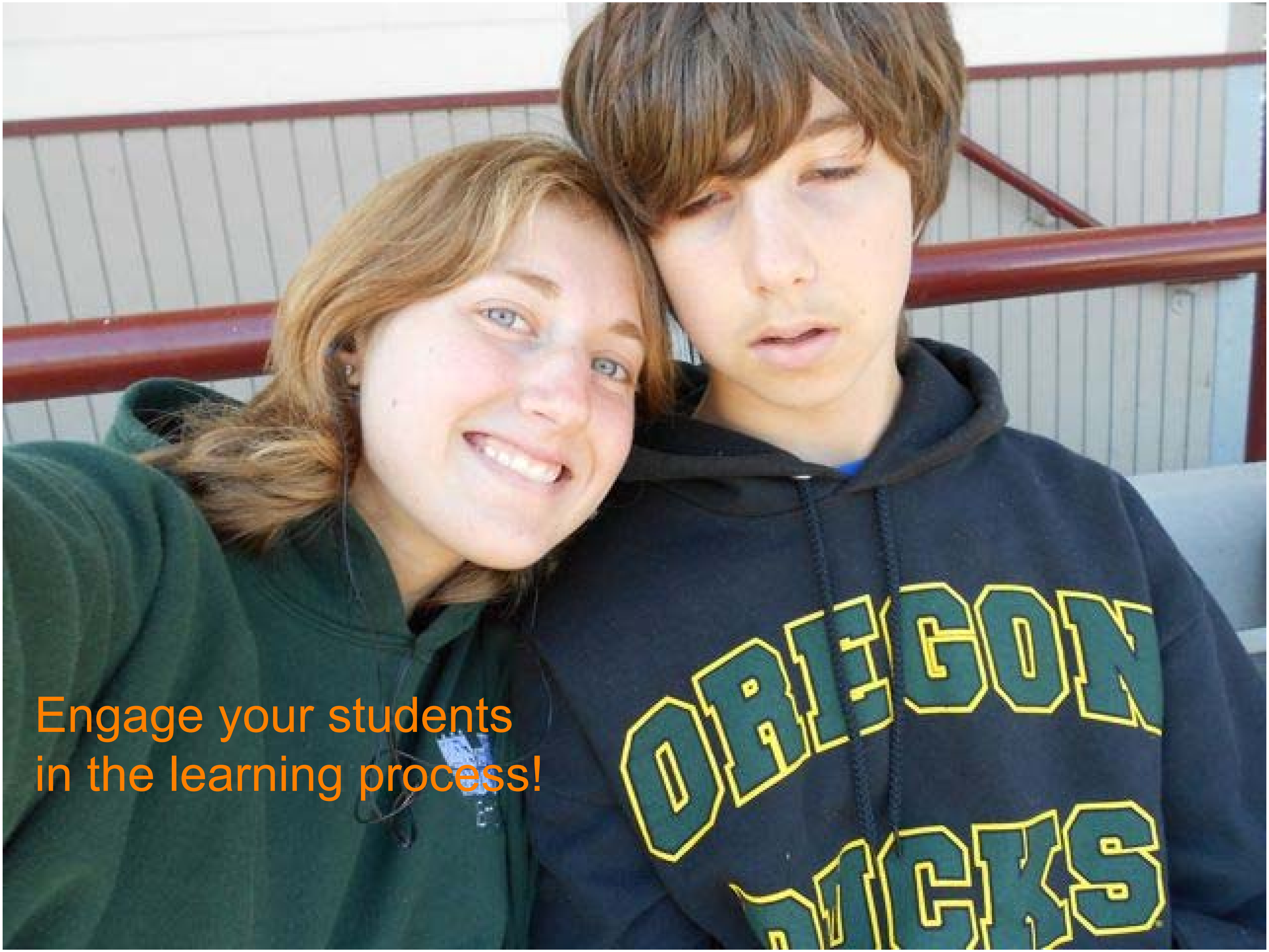
There are four *RTP* modules published by Wiley

Module 1: *Mechanics* ***Module 2:*** *Heat and Thermodynamics*

Module 3: *Electricity and Magnetism* ***Module 4:*** *Light and Optics*



For more information on *RTP* go to www.wiley.com and search RealTime physics.


Engage your students
in the learning process!
OREGON

Discussion

What changes in teaching strategies are needed to make a lecture classroom a more active learning environment?

How do ILDs accomplish this?

How could ILDs be used in a "flipped" class?

What would you need in order to implement ILDs in your introductory physics course?

Other questions or comments?