The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2234-12

Meeting of Modern Science and School Physics: College for School Teachers of Physics in ICTP

27 April - 3 May, 2011

Engaging students in the learning process in the introductory physics course

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Engaging Students in the Learning Process in the Introductory Physics Course

Meeting of Modern Science and School Physics: College for School Teachers of Physics in ICTP

April 27, 2011

Thank you

The Abdus Salam
International Centre for Theoretical Physics

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

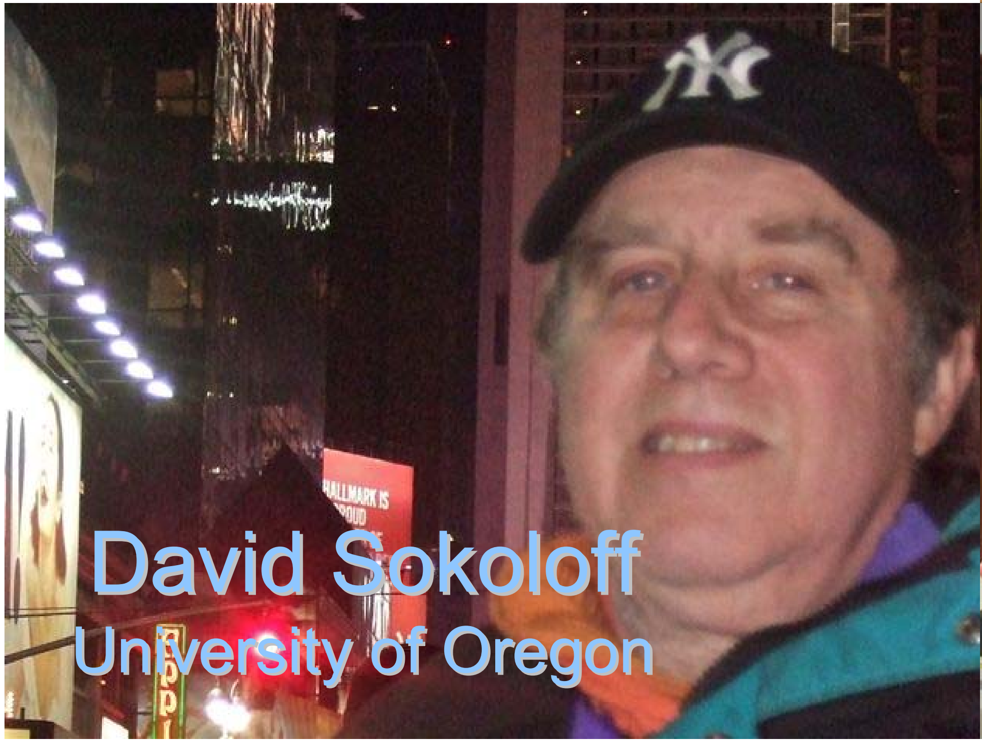
IAEA
International Atomic Energy Agency

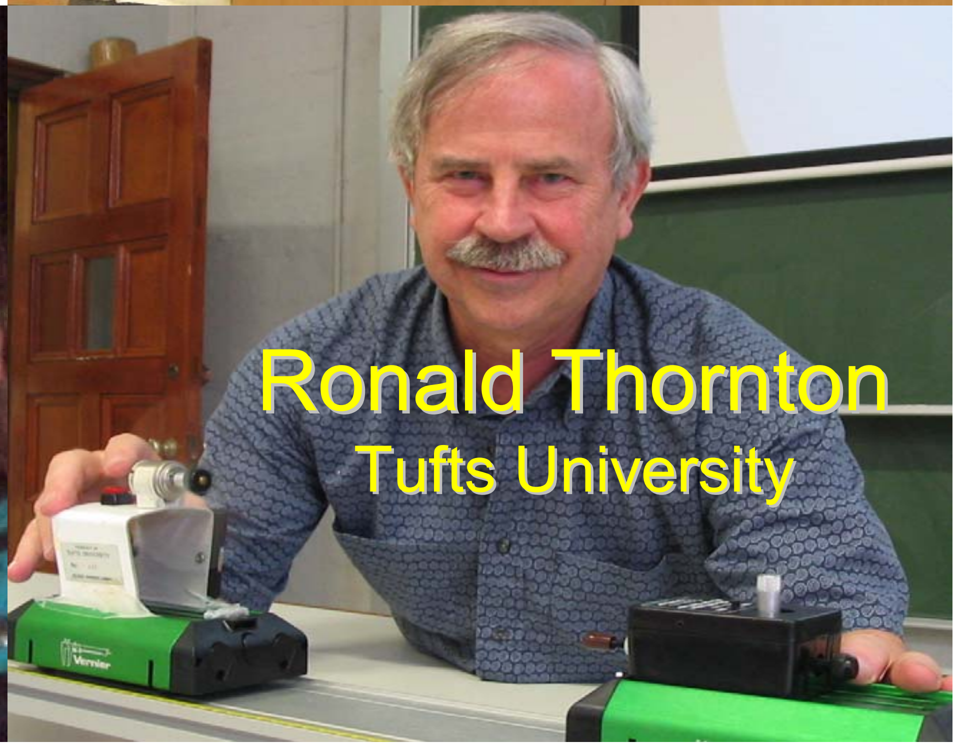
and especially *Prof. Andrey Varlamov*

for inviting me!

Winner of the *2010 American Physical Society Excellence in Physics Education Award*

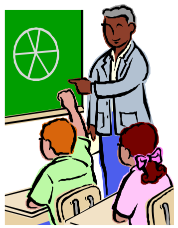
25 years of physics education research, development and dissemination.





Thank You to:

National Science Foundation
WHERE DISCOVERIES BEGIN



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

The Problem

- Students come into the introductory physics course at the high school or college level with definite views (often wrong) about physics concepts based on their experiences.
- Physics education research shows that the vast majority of students leave a traditional introductory physics course with the same (incorrect) views, and little understanding of physics concepts.
- Research done in many forms (student interviews, open-ended questions, short-answer questions, well-designed multiple choice questions) reaches the same conclusion.
- Result appears to be consistent for traditional methods of instruction, regardless of the skill of the instructor.

I will not learn concepts in physics class

I will not learn concepts in physics class

I will not learn concepts in physics class

I will not learn concepts in physics class

I will not learn concepts in physics class

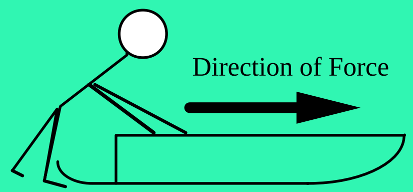
I will not learn concepts in physics class

The *Force and Motion Conceptual Evaluation (FMCE)*-Research Based

- 47 multiple choice questions based on previous research using open-ended assessments and interviews.
- Questions asked in a number of different forms and contexts.
- Makes possible tracking of student progress and persistence of conceptual learning during a course.
- Note: complete *FMCE* along with two journal articles on active learning are on the School CD.

Example: Natural Language Questions from the *Force and Motion Conceptual Evaluation*

A sled on ice moves in the ways described in questions 1-7 below. *Friction is so small that it can be ignored.* A person wearing spiked shoes standing on the ice can apply a force to the sled and push it along the ice. Choose the <u>one</u> force (**A** through **G**) which would **keep the sled moving** as described in each statement below.

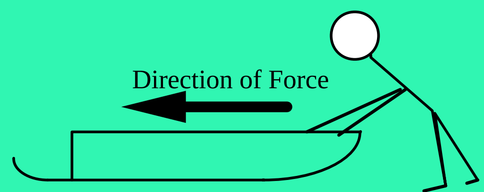


A. The force is toward the **right** and is **increasing** in strength (magnitude).

B. The force is toward the **right** and is of **constant** strength (magnitude).

C. The force is toward the **right** and is **decreasing** in strength (magnitude).

D. No applied force is needed



E. The force is toward the **left** and is **decreasing** in strength (magnitude).

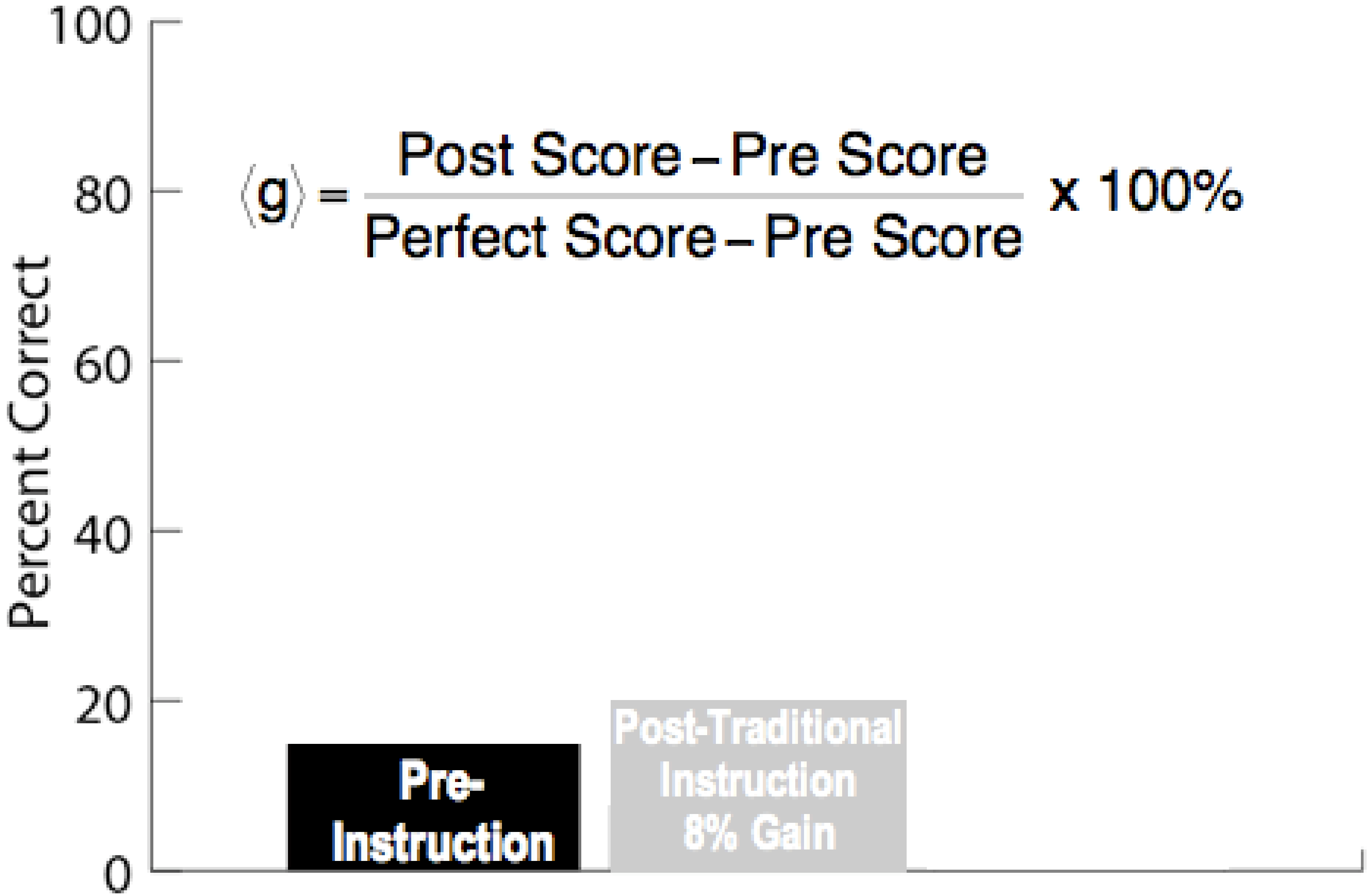
F. The force is toward the **left** and is of **constant** strength (magnitude).

G. The force is toward the **left** and is **increasing** in strength (magnitude).

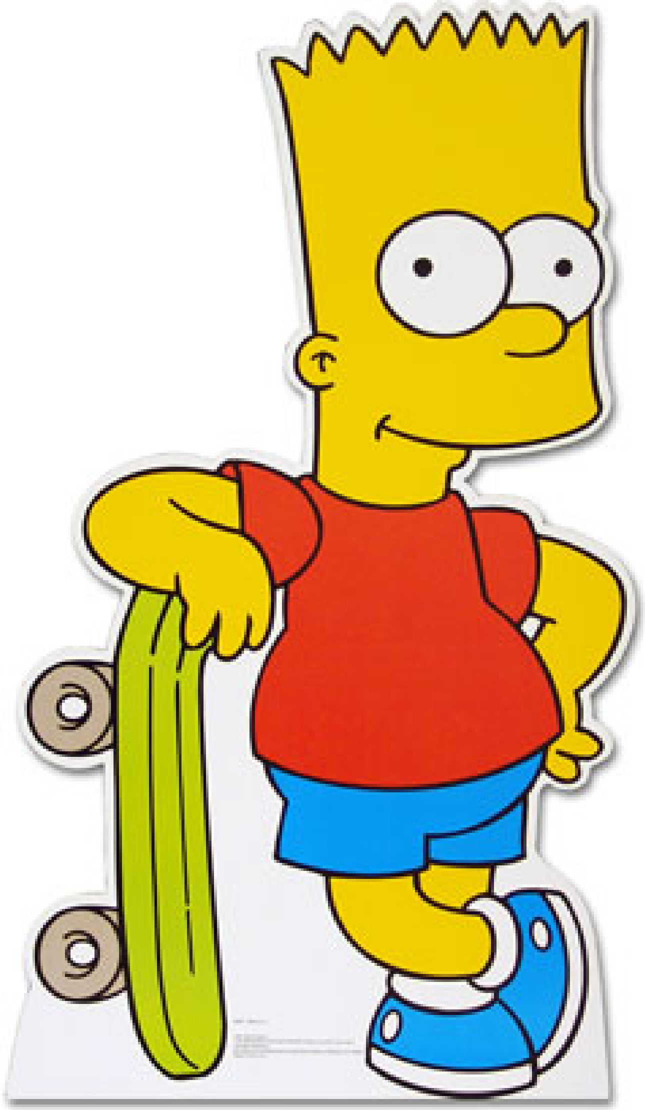
Questions 1-7 describe different simple motions of the sled, e.g. moving toward the right at a steady velocity, moving toward the right and speeding up at a steady rate . . .

Not this kind of test . . .

Final Page of the Medical Boards . . .



100
80
60
40
20
0
Percent Correct
$\langle g \rangle = \frac{\text{Post Score} - \text{Pre Score}}{\text{Perfect Score} - \text{Pre Score}} \times 100\%$
Pre-Instruction
Post-Traditional Instruction 8% Gain



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

The Proposed Solution . . .

Active Learning Environments

But, what is Active Learning?

And now for something different . . .

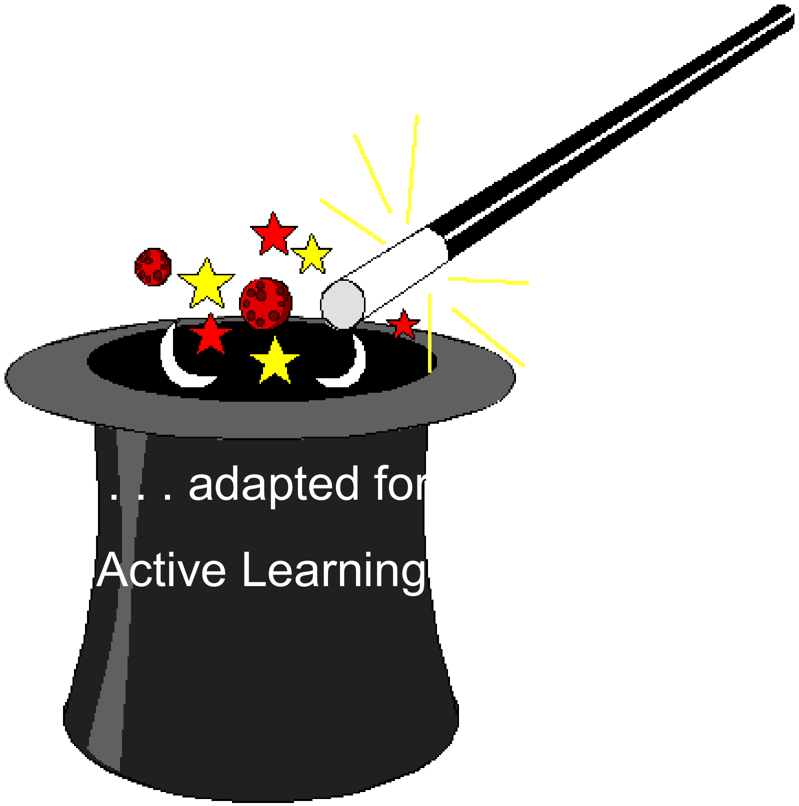
I will try to model active learning for you—make you the ***center*** of the learning process rather than lecturing to you . . . because research shows that active learning is more effective for students!

In a mini-workshop of just four hours, I don't expect to change the way you teach. But I hope you will consider changing to active learning strategies that have been research-validated.

My hope is that in the near future we can present an ICTP ***School on Active Learning in Physics***.

An Example of Active Learning

An optics magic trick. . .



Reappearance of a Broken Test Tube

- I will crush a test tube into many pieces
- Then, with a magic fluid, a magic wand and the magic word:

“ICTP”

- I will make the tube whole again!

Discussion Questions for Optics *Magic*: *Reappearing Test Tube*

1. How do you think that the test tube was made to reappear?
2. Why can you see a test tube in air or in water, but not in the magic fluid? What is special about the magic fluid?
3. What property of transparent media determines whether reflection takes place at the boundary between them? What has to be true about this property for the two materials in order for reflection to take place?
4. What about the light that is transmitted through the test tube? How is it affected when the test tube is in the magic fluid and when the test tube is in air?

Characteristics of Passive vs. Active Learning Environments

Passive Learning	Active Learning

Passive Learning	Active Learning
Instructor’s role is authority.	The physical world is the authority. Instructor’s role is guide.
Students' naïve beliefs not challenged.	Learning cycle: prediction/ observation/comparison. Challenges students’ beliefs.
Collaboration with peers often discouraged.	Collaboration and shared learning with peers is encouraged.
Experimental results are often presented as facts in lecture.	Results from real experiments are observed in understandable ways—often in real time with microcomputer-based tools.
Laboratory work, if any, is used to confirm theories "learned" in lecture.	Laboratory work is used to learn basic concepts.

One of the accomplishments of the Activity Based Physics Group has been a number of uses of technology to explore the physical world . . .

You will work hands-on with some of these tomorrow afternoon, and see others this afternoon.

These tools are very nifty, but it is their careful design that has enabled significant changes in pedagogy. . .

Activity Based Physics Suite

- Published by John Wiley & Sons.
- All based on same pedagogy, same learning cycle, same notation.
- Instructor chooses how to design his/her course by combining materials.

RealTime Physics Laboratories (RTP)

Interactive Lecture Demonstrations (ILDs)

Workshop Physics

U of Maryland Tutorials

Explorations in Physics

Understanding Physics

Physics with Video Analysis

Tomorrow afternoon you will work with activities from *RealTime Physics* labs.

For today, the question is can an active learning environment be created in a large (or small) lecture?

Yes, through the use of

Interactive Lecture Demonstrations (ILDs)

“Dr. Sokoloff, may I be excused?
My brain is full!”

Examples of *ILDs* in Mechanics

- I will show you demonstrations and ask you to make INDIVIDUAL predictions on a Prediction Sheet.

  Note: Predictions are NEVER graded, but points may be awarded for attendance and participation.
- Then I will ask you to discuss your predictions with your nearest neighbor(s). See if your small group can reach a consensus on the correct prediction.
- Finally, I will do the demonstrations with the results displayed. I will ask you to discuss what you observe with the whole group.

Hand in This Sheet Name ________________

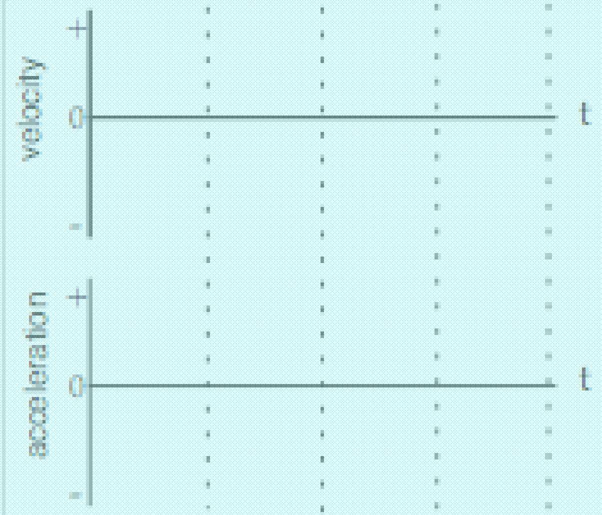
SAMPLE INTERACTIVE LECTURE DEMONSTRATION PREDICTION SHEET

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.

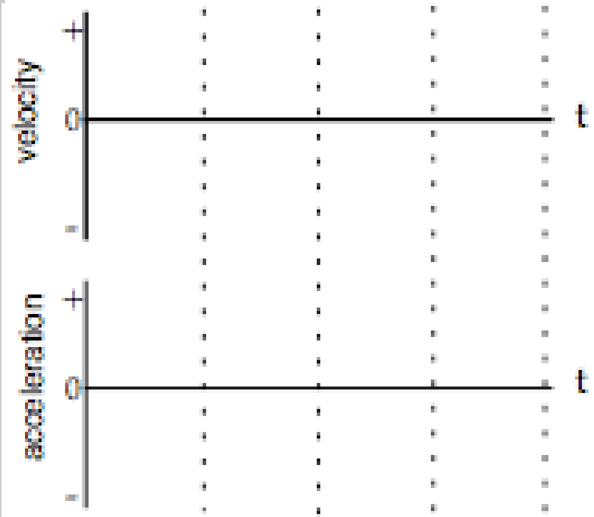
<u>Demonstration 1:</u> Sample Kinematics Demo

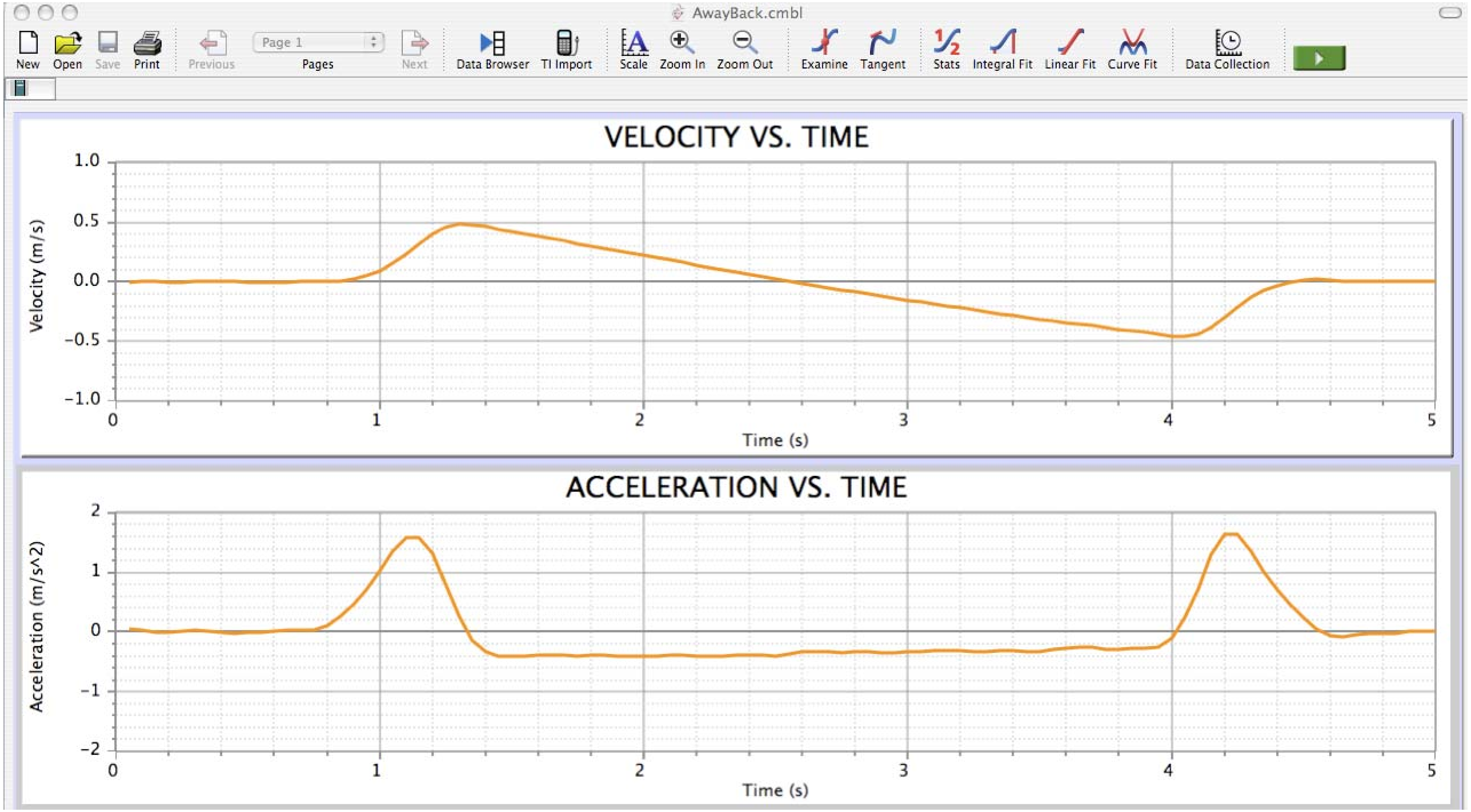
A cart is subjected to a constant force in the direction towards the motion detector. Sketch on the axes on the right your predictions of the velocity and acceleration of the cart after it is given a short push away from the motion detector (and is released). Sketch velocity and acceleration as the cart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



<u>Demonstration 2:</u> Inventing Gravitational Force Demo

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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Data Collection
VELOCITY VS. TIME
Velocity (m/s)
1.0
0.5
0.0
-0.5
-1.0
0
1
2
3
4
5
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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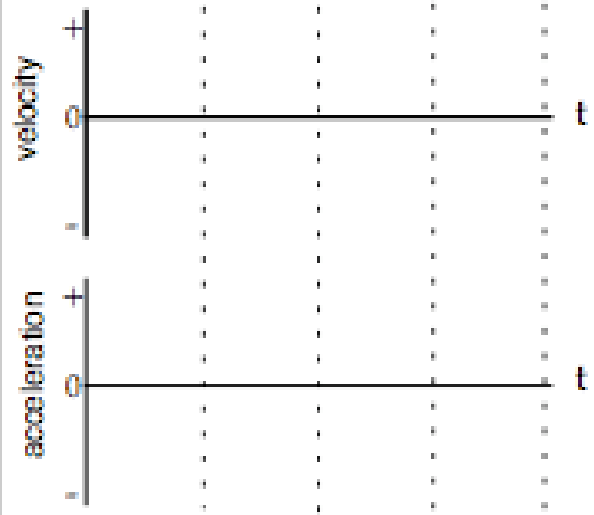

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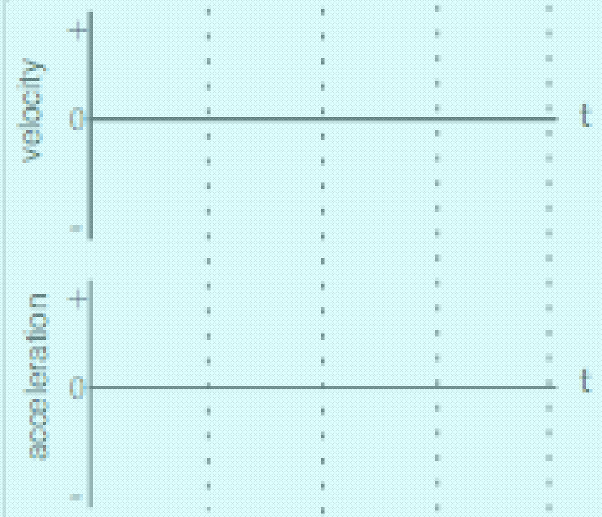

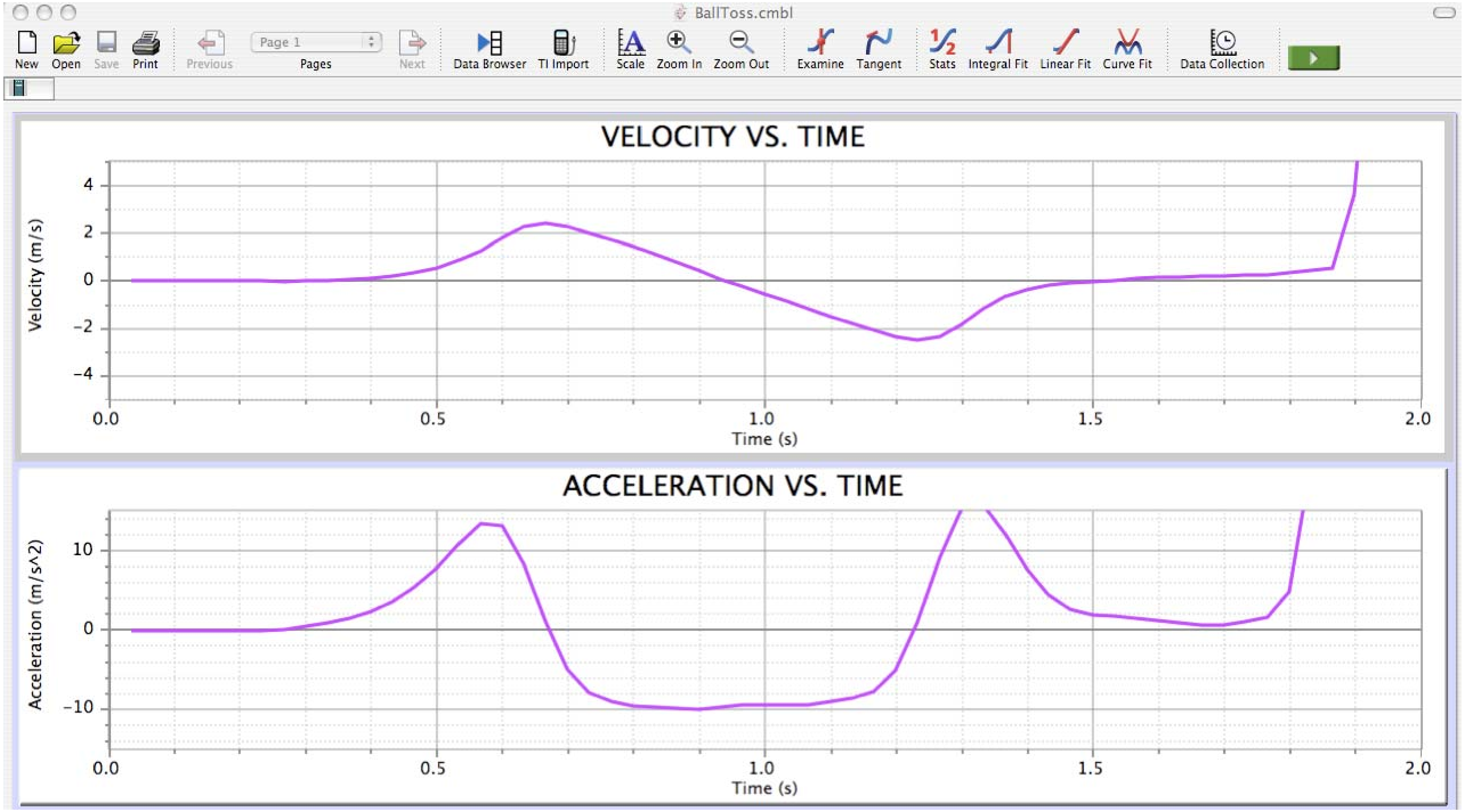
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Examine
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Stats
Integral Fit
Linear Fit
Curve Fit
Data Collection
VELOCITY VS. TIME
Velocity (m/s)
4
2
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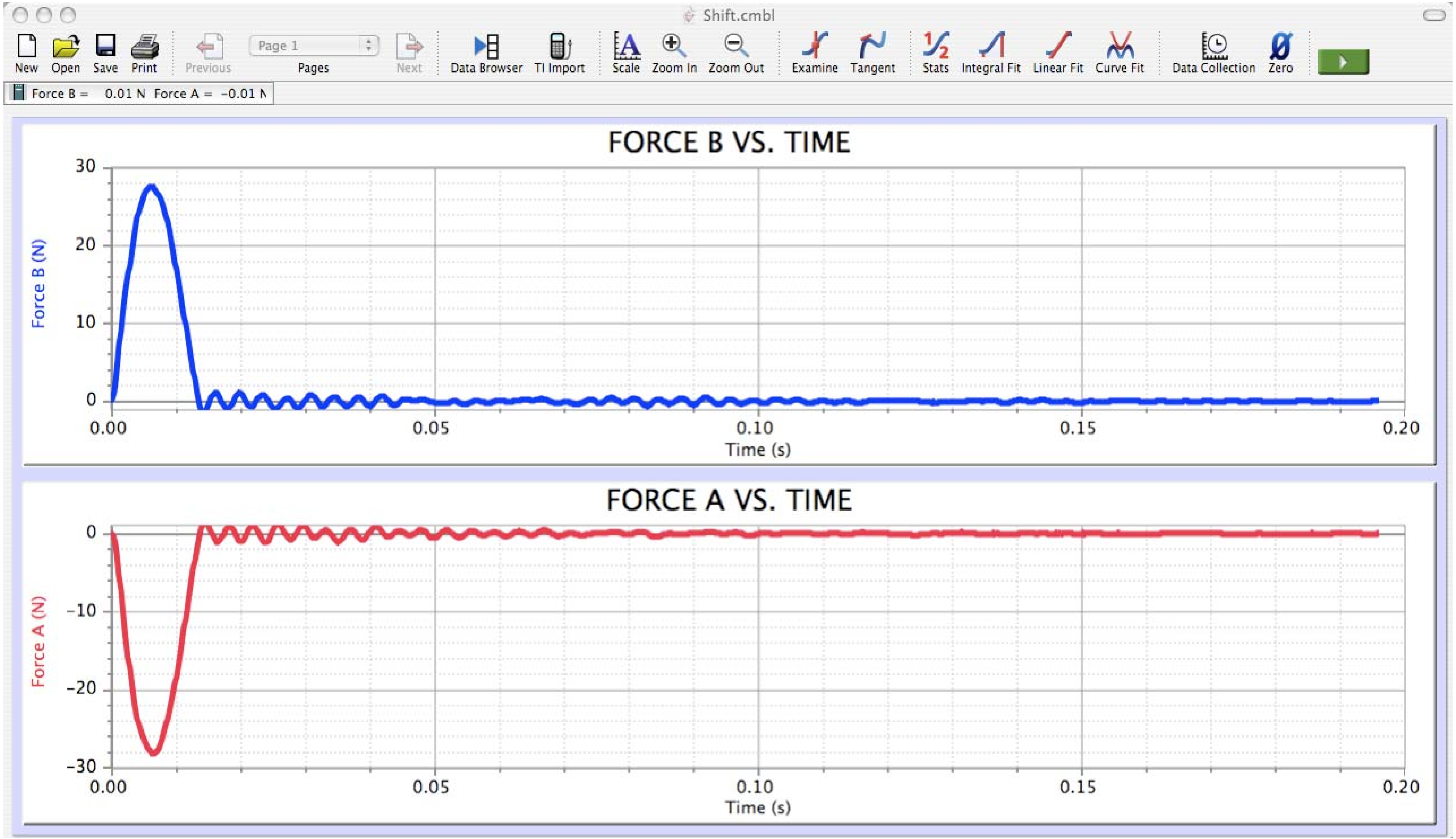
−2
−4
0.0
0.5
1.0
1.5
2.0
Time (s)
ACCELERATION VS. TIME
Acceleration (m/s^2)
10
0
−10
0.0
0.5
1.0
1.5
2.0
Time (s)

Demonstration 4: **Sample Forces in Collisions Demonstration**

Two carts collide with each other. Before the collision, Cart 1 is moving towards Cart 2, which is at rest. Cart 1 has three times the mass of Cart 2. Describe in the space below your prediction for the force exerted by Cart 1 on Cart 2 compared to the force exerted by Cart 2 on Cart 1. (You may state your prediction in words or graphically.)


Vernier
PASCar



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Linear Fit
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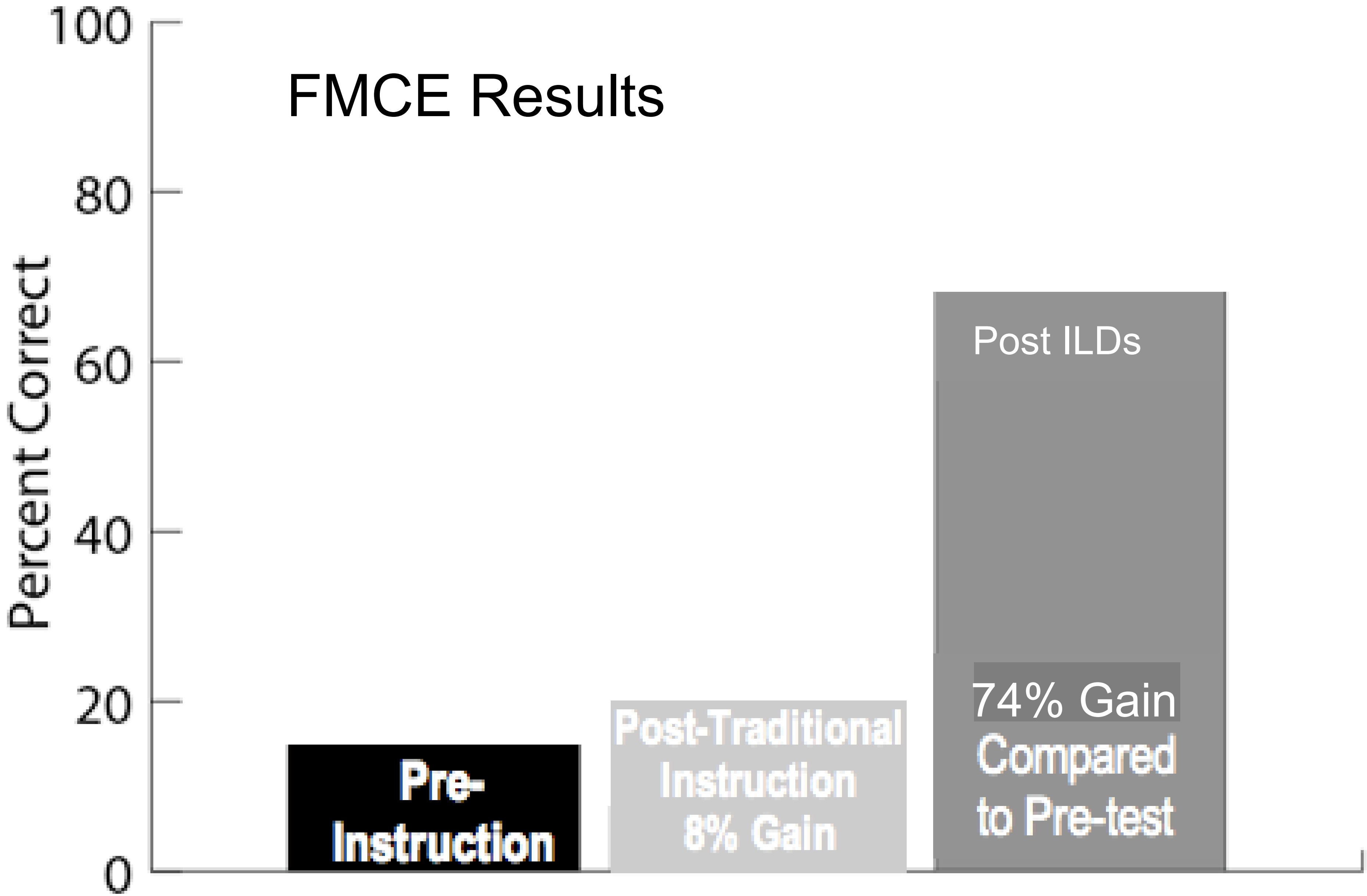
Data Collection
Zero
Force B = 0.01 N Force A = -0.01 N
FORCE B VS. TIME
Force B (N)
30
20
10
0
0.00
0.05
0.10
0.15
0.20
Time (s)
FORCE A VS. TIME
Force A (N)
0
-10
-20
-30
0.00
0.05
0.10
0.15
0.20
Time (s)

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. Ask each student to 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.

Do students learn concepts from *ILDs*?


FMCE Results
Percent Correct
100
80
60
40
20
0
Pre-Instruction
Post-Traditional Instruction 8% Gain
Post ILDs
74% Gain Compared to Pre-test

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*.

Characteristics of the Curricula that Make Them Effective

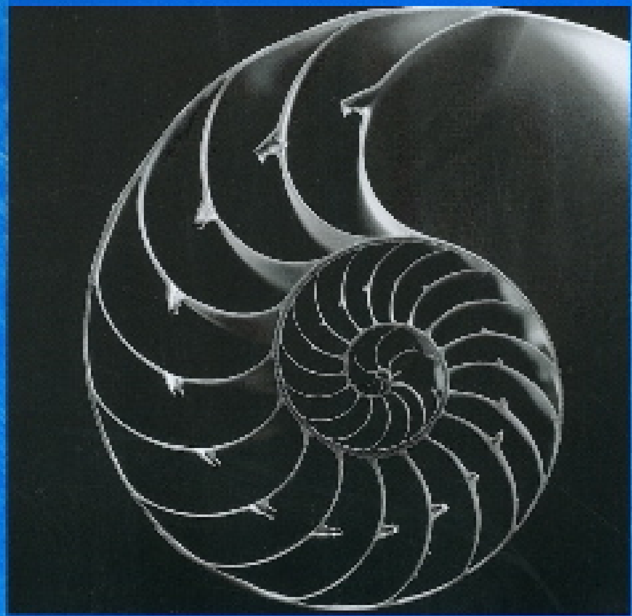
- Making predictions requires students to consider their beliefs before making observations of the physical world. The *RTP* labs and *ILDs* build upon the knowledge that students bring into the course.
- With *ILDs*, the process of prediction, defending the prediction in a small group, and writing down 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.

Modes of *ILD* Use

- Introduction of concepts.
- Review or clarification of concepts.
- In place of or in conjunction with lab activities that are difficult for students to carry out.

Interactive Lecture Demonstrations

Active Learning in Introductory Physics



THE PHYSICS SUITE

DAVID R. SOKOLOFF
RONALD K. THORNTON

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 on an object that are incident on the lens will be focused to the same point on the image.
- In these *ILDs*, two miniature light bulbs are used as two discrete object point sources of light.

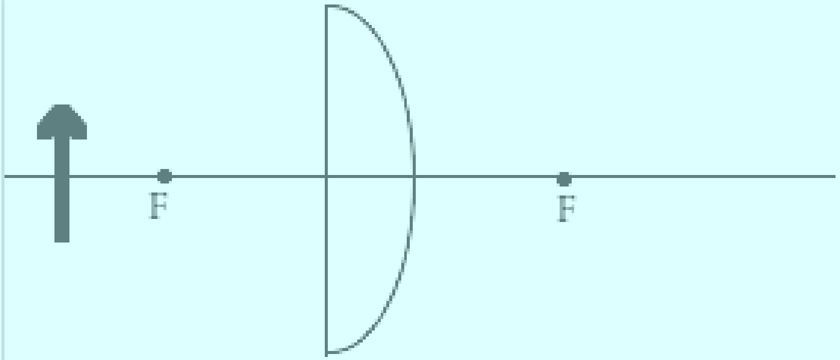
Hand in this sheet ......Name ______________________

INTERACTIVE LECTURE DEMONSTRATIONS
PREDICTION SHEET—**IMAGE FORMATION WITH LENSES**

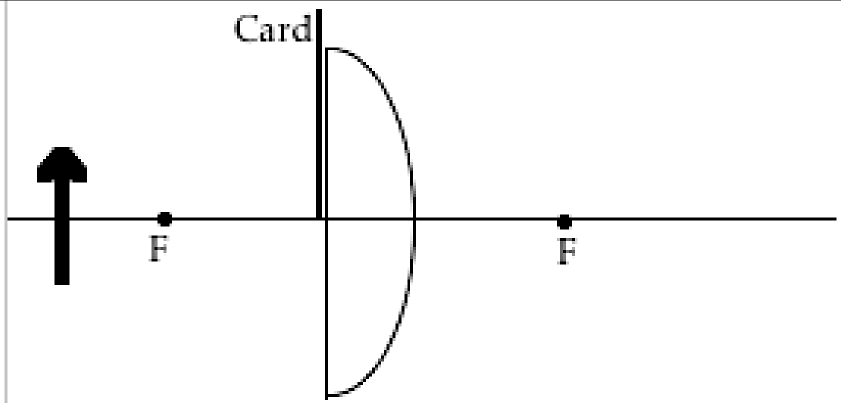
Directions: This sheet will be collected. Write your name at the top to record your presence and participation in these demonstrations. Follow your instructor's directions. You may write whatever you wish on the attached Results Sheet and take it with you.

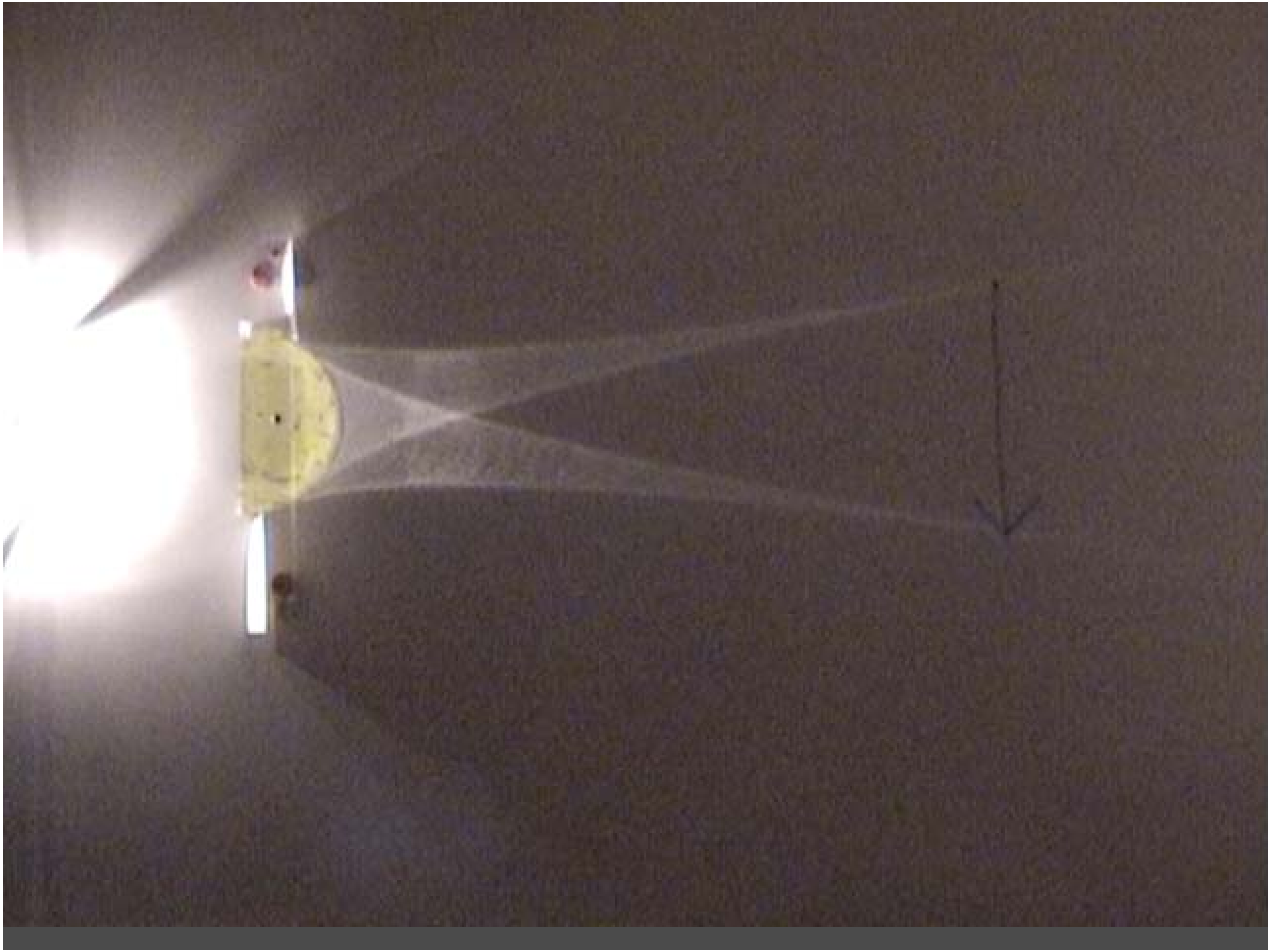
Demonstration 1: You have a converging lens. An object in the shape of an arrow is positioned a distance larger than the focal length to the left of the lens, as shown in the diagram on the right. Draw several rays from the head of the arrow and several rays from the foot of the arrow to show how the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





Hand in this sheet   Name ____________________

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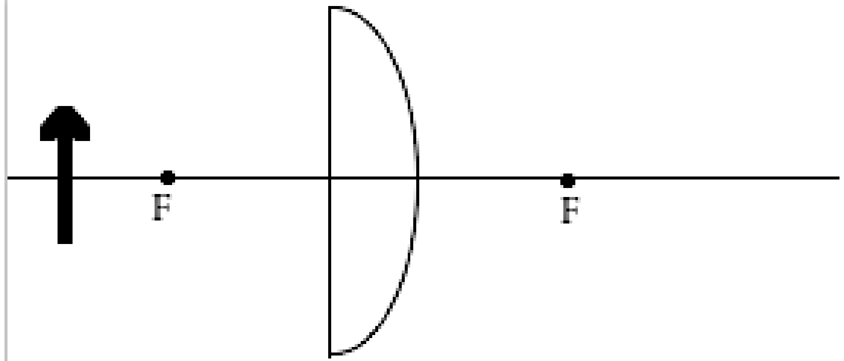

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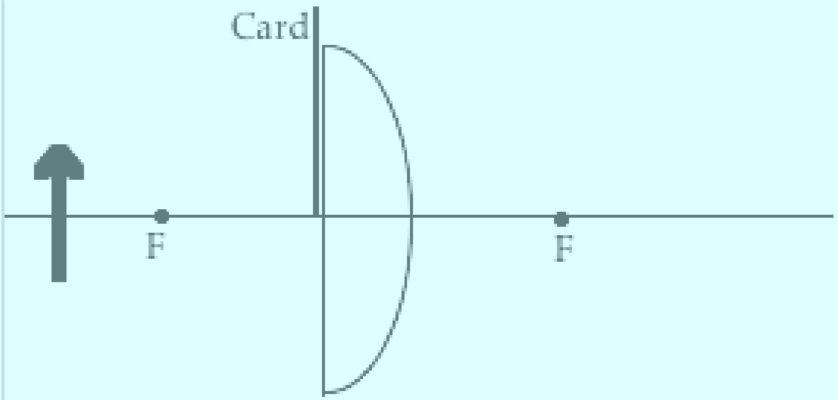
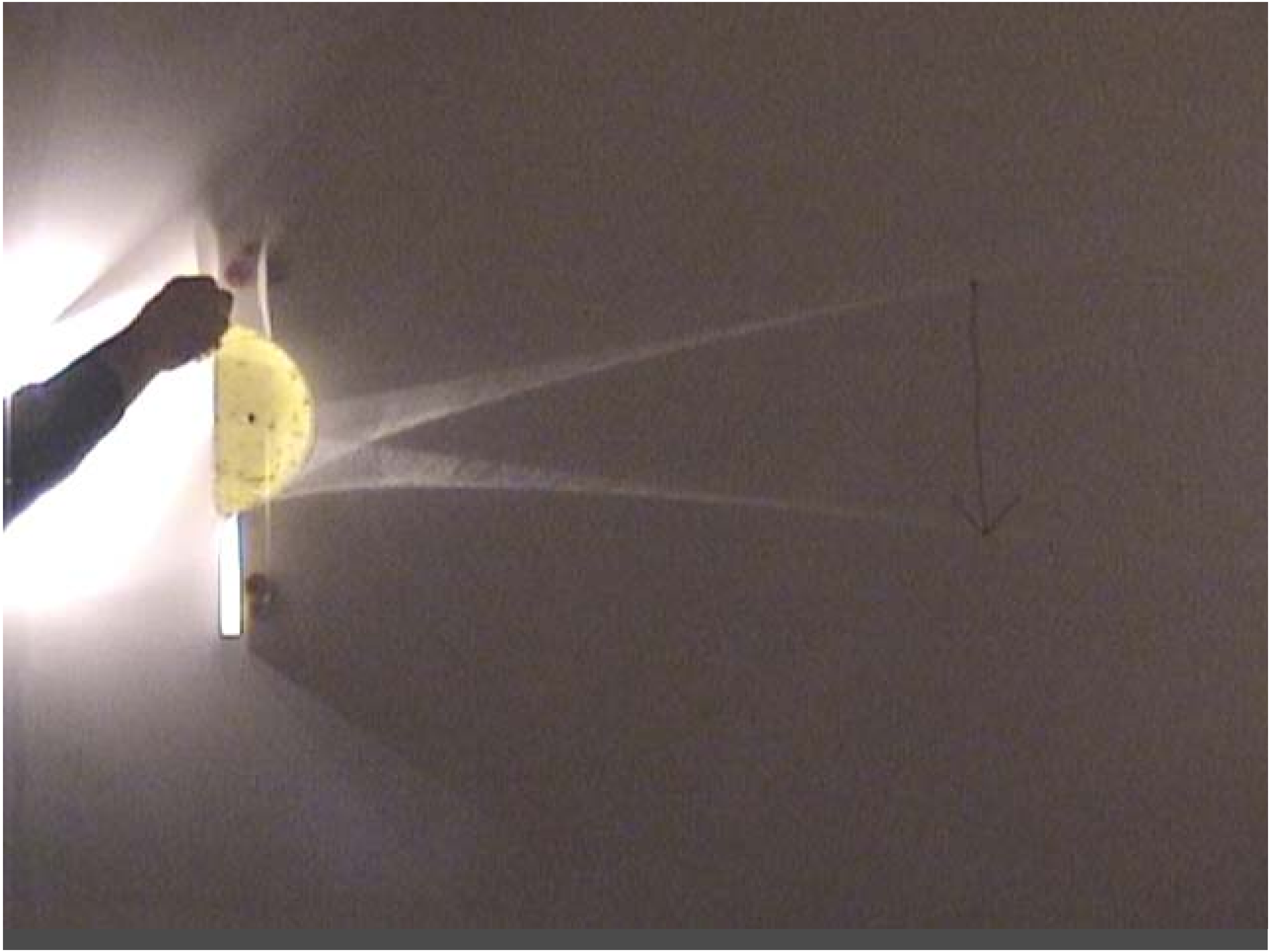
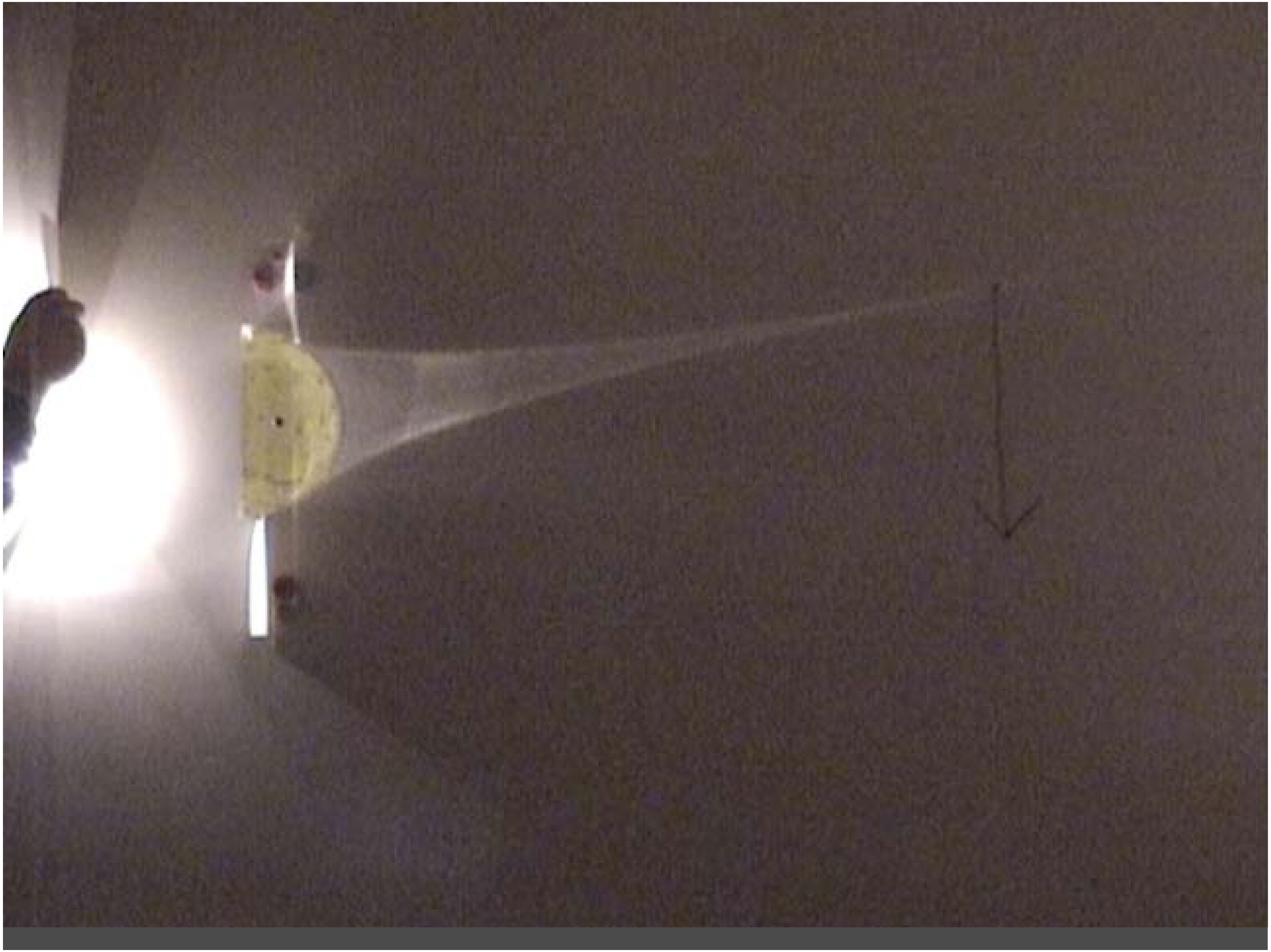




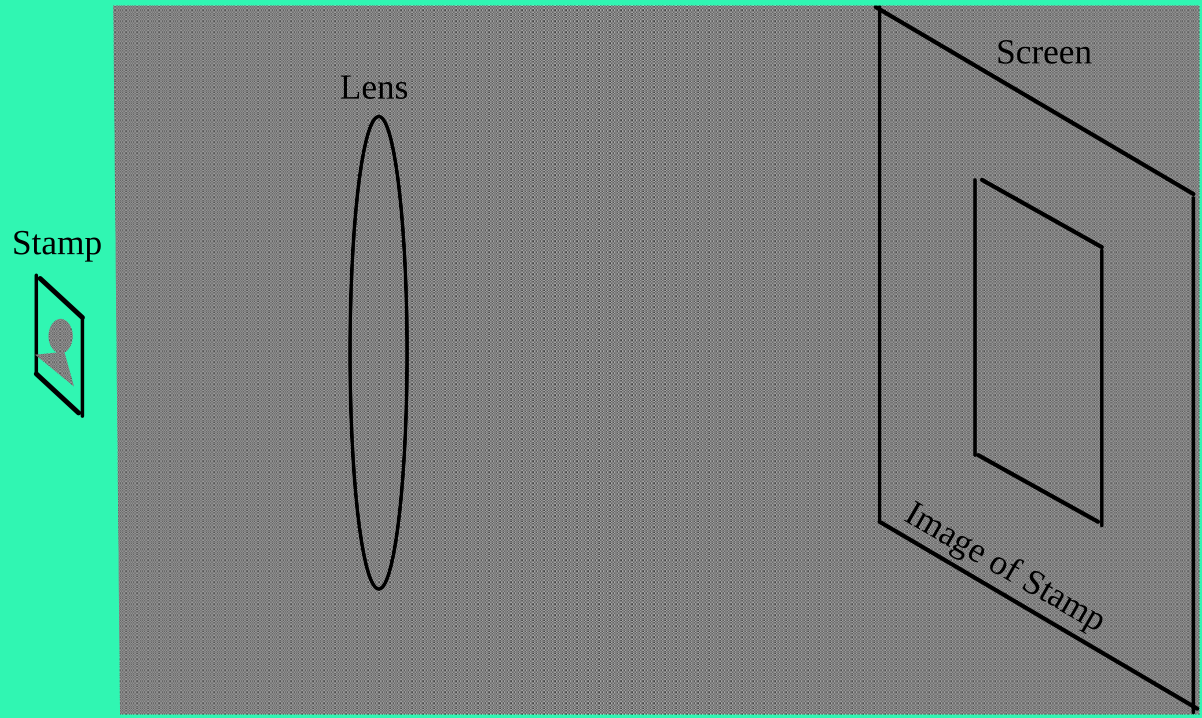


Do students learn with these *ILDs*?

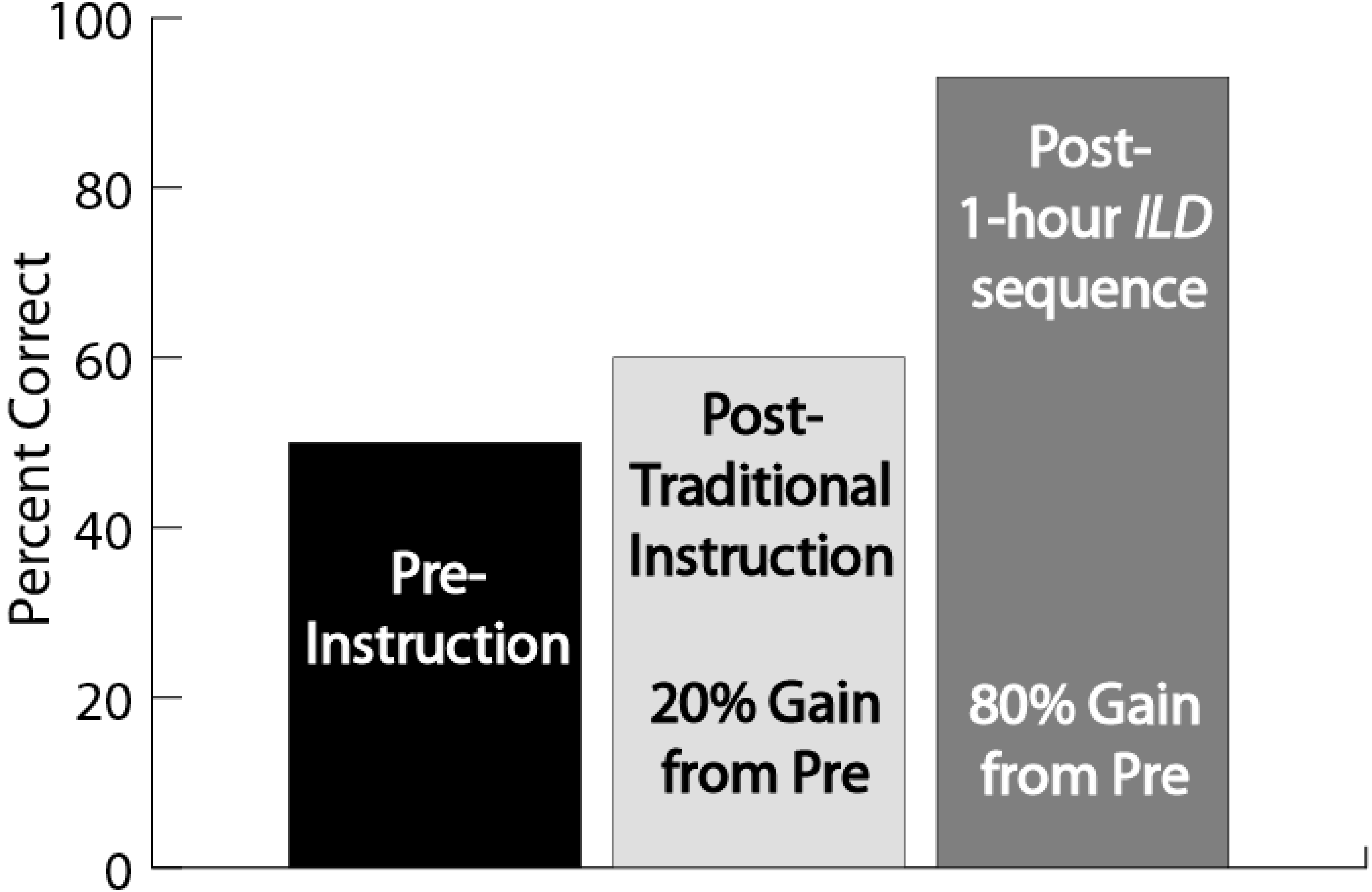
Image Formation Questions from the *Light and Optics Conceptual Evaluation*

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.

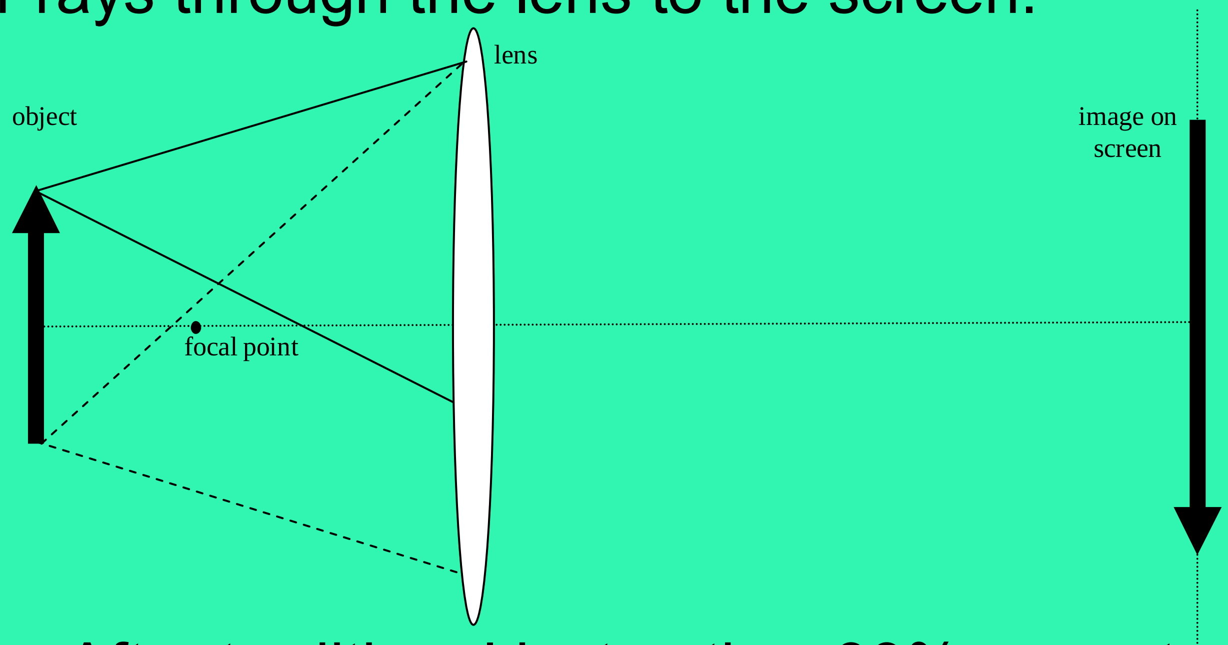
Choose the correct answer for each question.



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 . . .


Percent Correct
100
80
60
40
20
0
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.



After traditional instruction 33% correct

After one lecture of *ILDs* 76% correct

64% normalized gain

ILDs Using a Personal Response System (Clickers)

Personal Response Systems have become ubiquitous . . . just about every physics department in the U.S. (including this one) has a system.

Useful Features

- Quick assessment of student knowledge and understanding for just in time teaching (JITT).
- Student responses are anonymous and not influenced by peers.
- Easy assessment and record keeping of student attendance and participation.
- Instantaneous feedback to class to stimulate interest.

The question is, what are <u>*effective*</u> (research validated) ways of using them to improve learning?

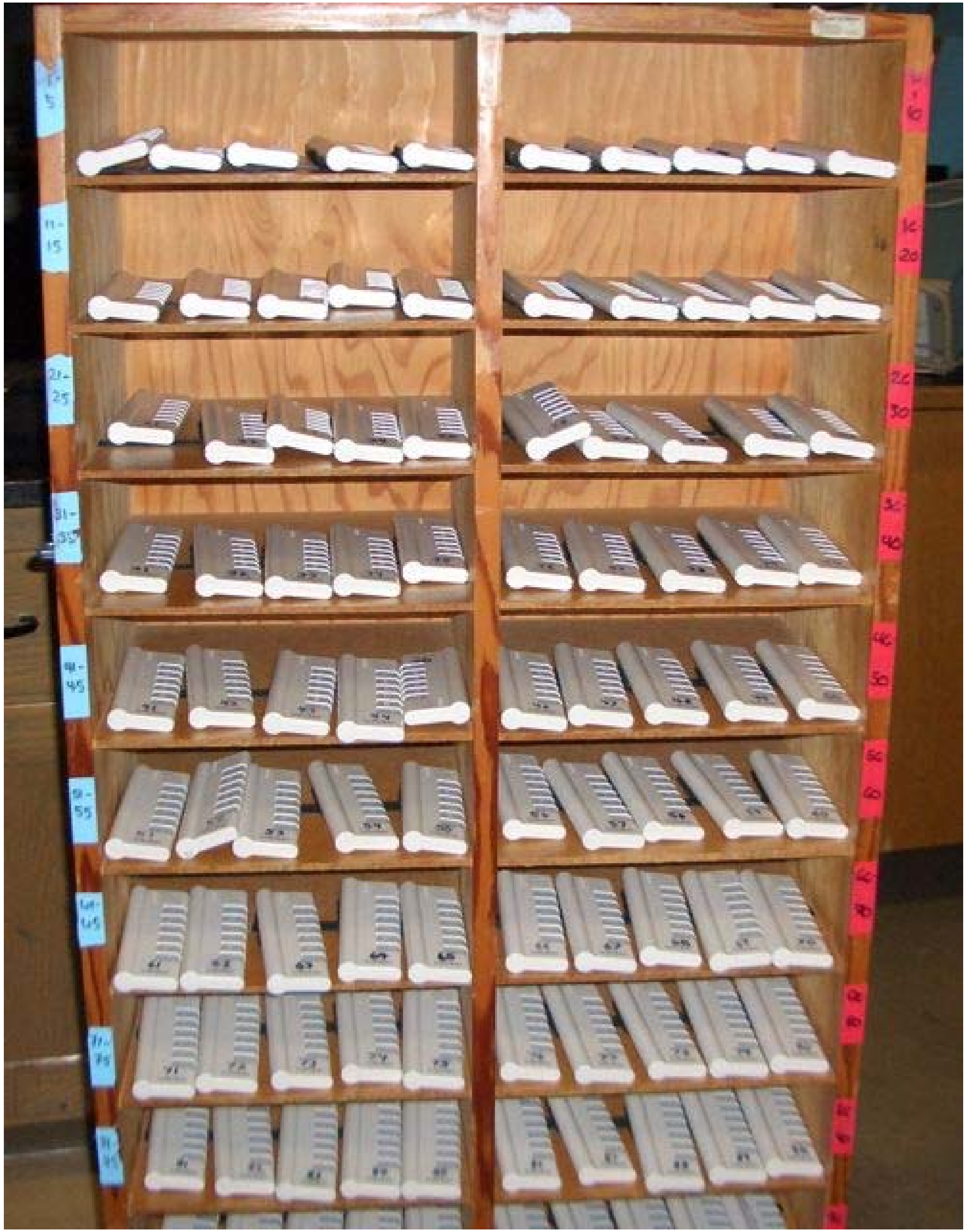
There are many commercial clicker systems--any will work

Advantages of i>clicker:

- Very easy to use. Easy to register students.
- No special formatting for questions. Screen image saved.
- Produces series of reports automatically, including attendance, all responses and analysis.

Disadvantages:

- Only five choices
- Not easy to paste student information into Excel.



To save students money, my department has purchased a set of clickers for use in many classes . . .

students pick up their assigned one at the beginning of lecture.

Modified *ILD* Procedure for Use with Clickers

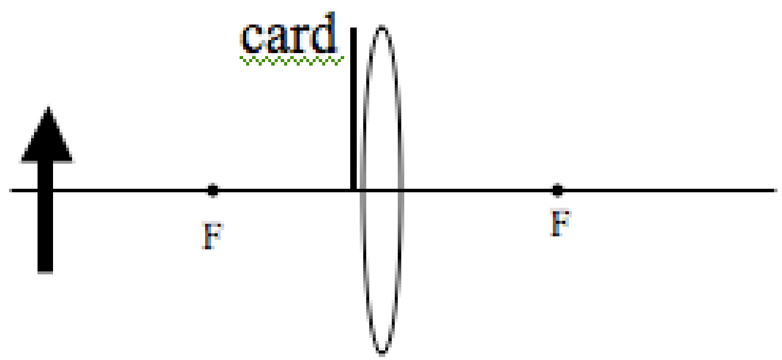
1. Describe the demonstration and do it for the class without results displayed.
2. Ask students to record individual predictions with the clickers. <u>Do not show histogram of class's predictions</u>.
3. Have the class engage in small group discussions.
4. Ask students to record individual predictions again with the clickers. Display the histogram of class's predictions.
5. Carry out the demonstration and display the results.
6. Ask a few students to describe the results and discuss them in the context of the demonstration. Students may make notes on the demonstration in their notebooks.
7. If appropriate, discuss analogous physical situations with different "surface" features.

Note:

Predictions are made using clickers to choose from given choices, rather than writing individual open-ended answers . . .

. . . this is a very different activity for students. It is not obvious that clicker ILDs should be as effective as regular ILDs.

Here's an example.

Demonstration 2: What will happen to the image if you block the top half of the *lens* with a card?	

A. Half of the image will disappear

B. The image will be whole but half as large

C. The image will disappear

D. The image will be dimmer

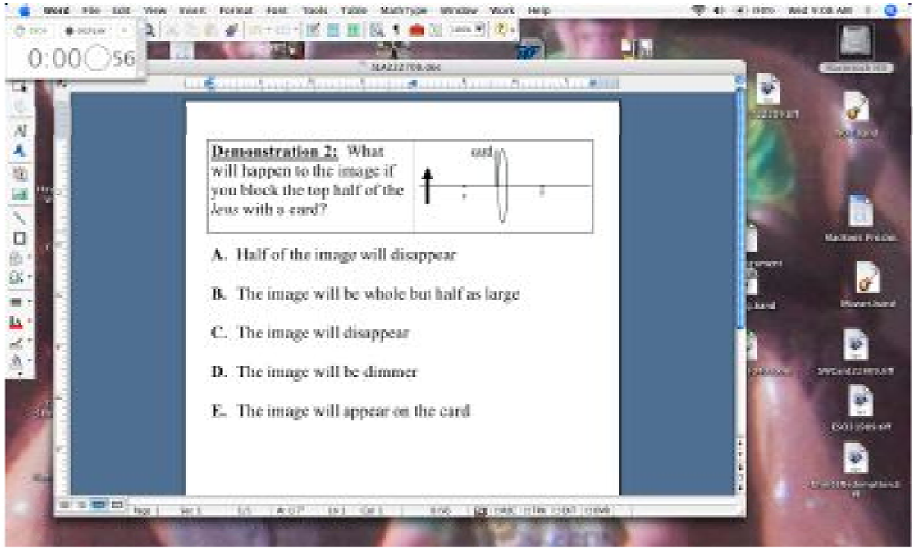
E. The image will appear on the card

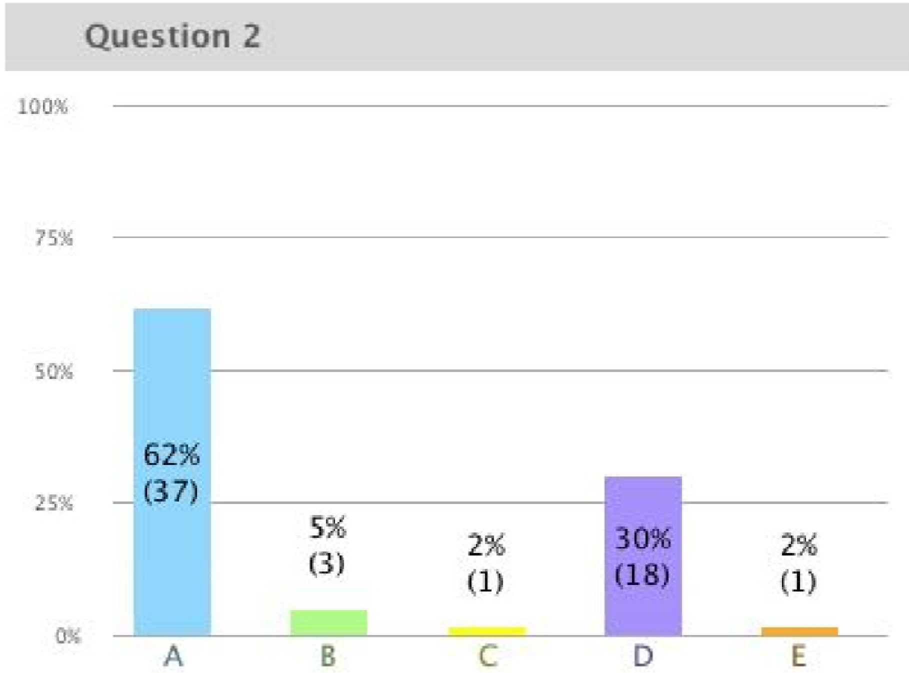
I>clicker Results After Traditional Instruction

Time Started: **9:08:43 AM**
Number of Responses: **60**
Number Missing: **5**

Correct Answer: D
Maximum Score **0.00**
Class Average **0.00**

Choice	A	B	C	D	E
Number	37	3	1	18	1
Percentage	62%	5%	2%	30%	2%
Performance Points	0	0	0	0	0



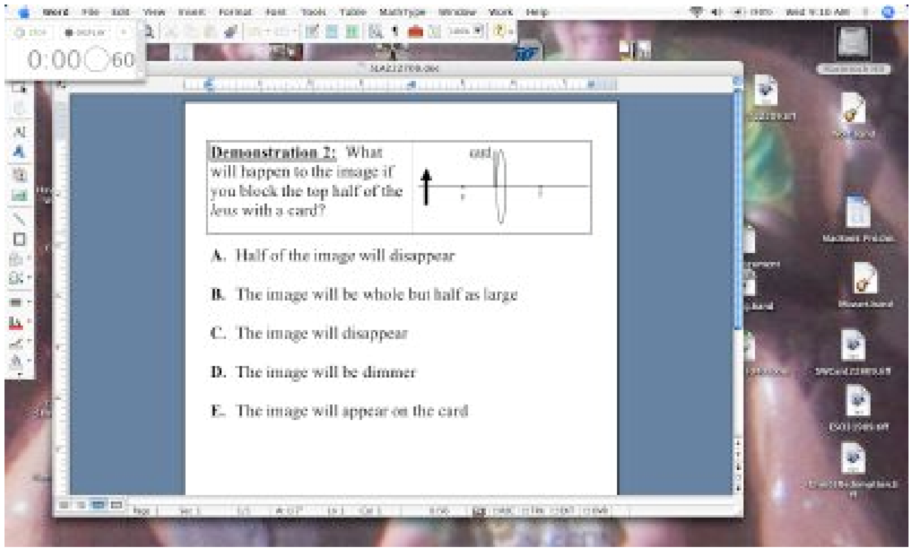


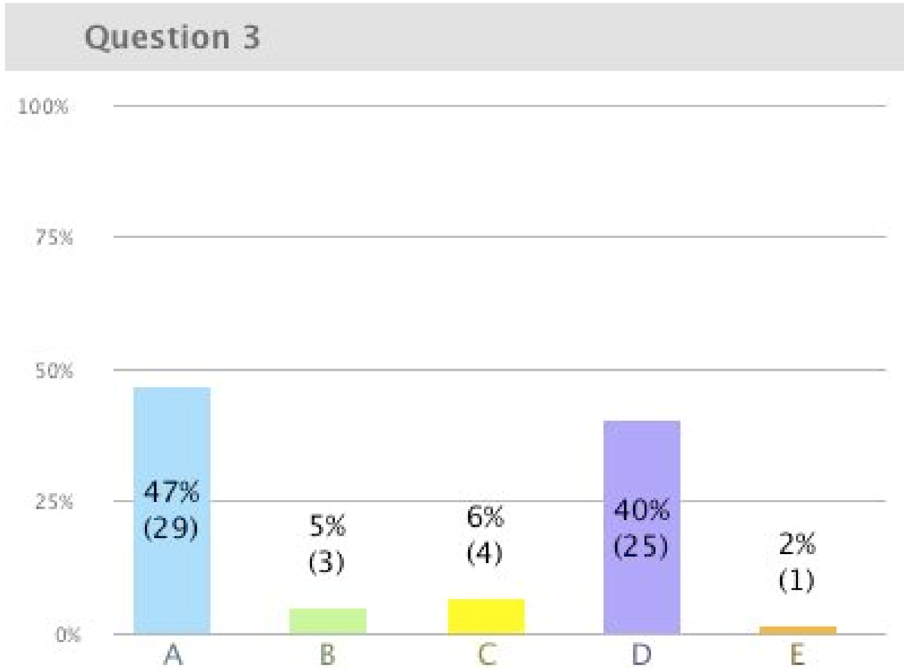
Results After Small Group Discussions
. . . note effect of peer discussion

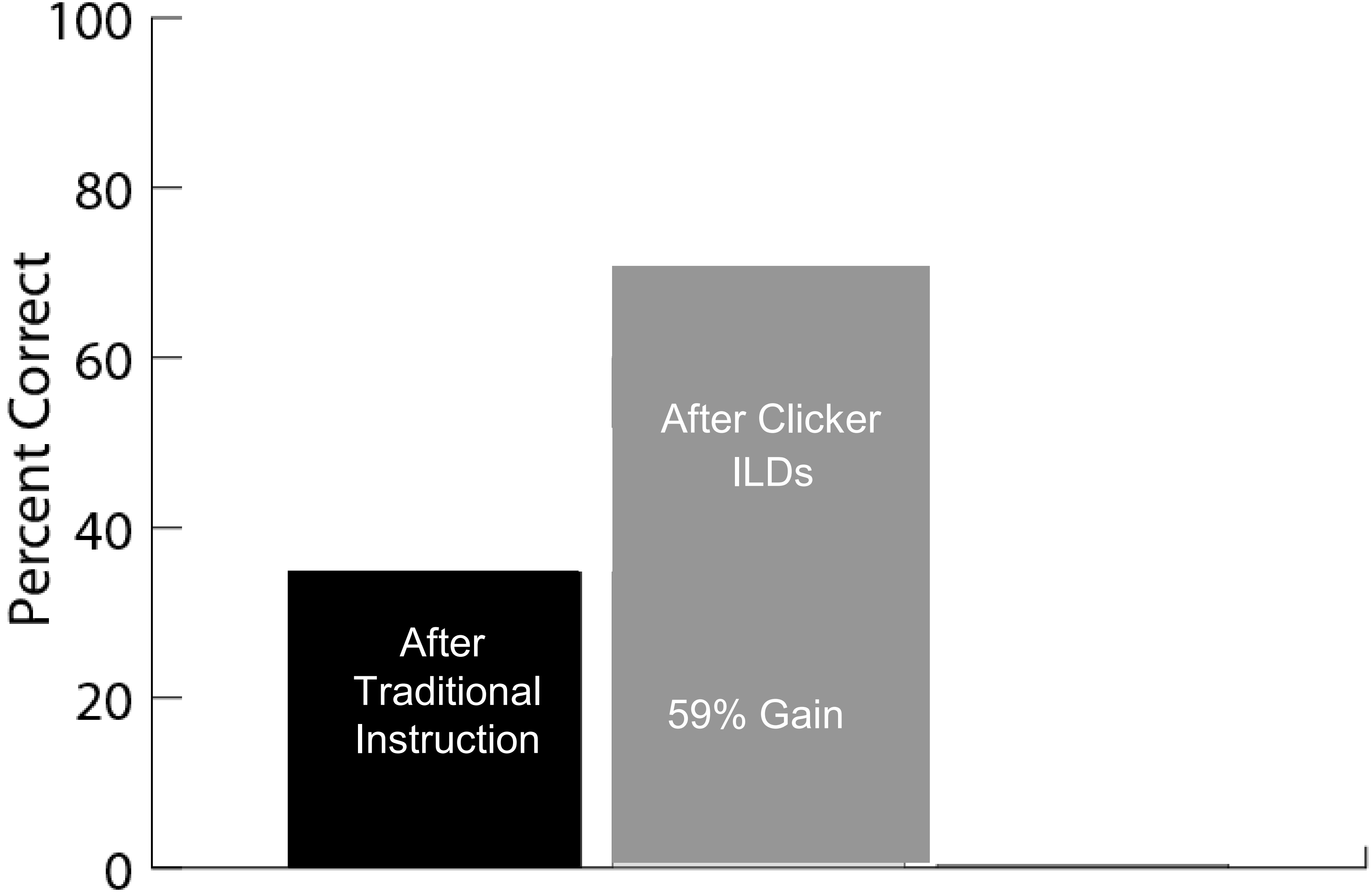
Time Started: **9:10:17 AM**
Number of Responses: **62**
Number Missing: **3**

Correct Answer: D
Maximum Score **0.00**
Class Average **0.00**

Choice	A	B	C	D	E
Number	29	3	4	25	1
Percentage	47%	5%	6%	40%	2%
Performance Points	0	0	0	0	0

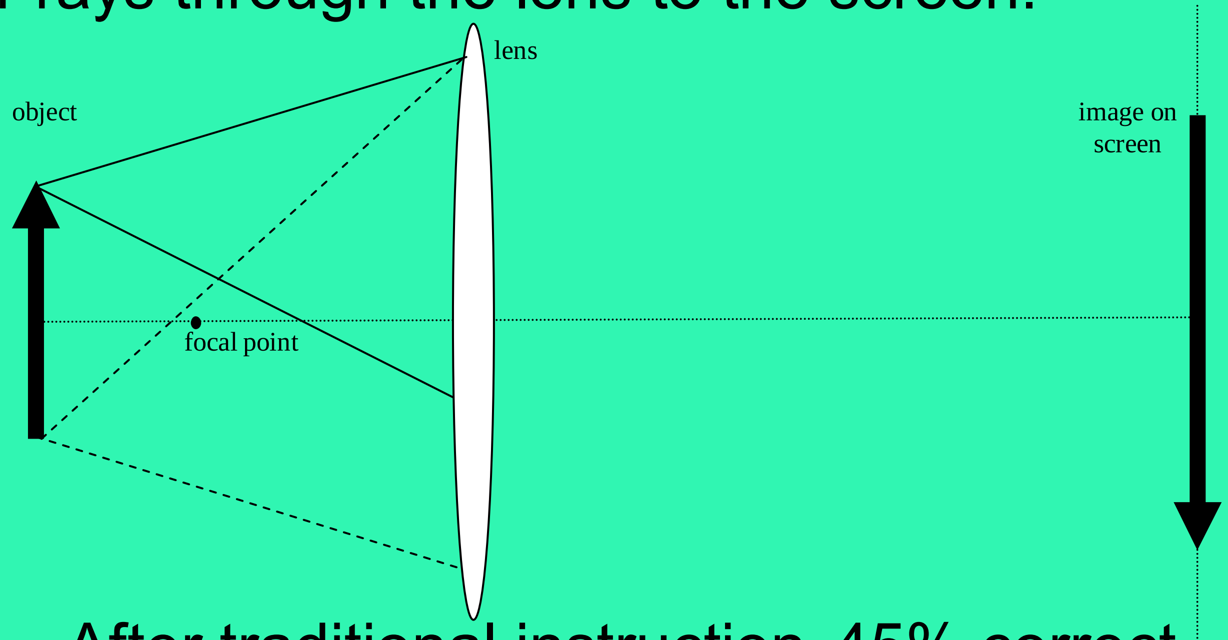






100
80
60
40
20
0
Percent Correct
After Traditional Instruction
After Clicker ILDs
59% Gain

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.



After traditional instruction 45% correct

After clicker *ILDs* 76% correct

Learning gains are still very dramatic!

Part II: Thursday, 15:00-17:30

We will meet in the Adriatico Informatics Lab on this floor, on the other side. Please be prompt, since our time will be tight.

Please be sure to bring the booklet, ***“Modern Methods of Teaching Physics”*** that is in your packet.

The End

RealTime Physics (RTP): Active Learning Labs . . .

A series of lab modules that use computer-based tools to help students develop important physics concepts in an active learning environment while acquiring vital laboratory skills.

RealTime Physics

Active Learning Laboratories

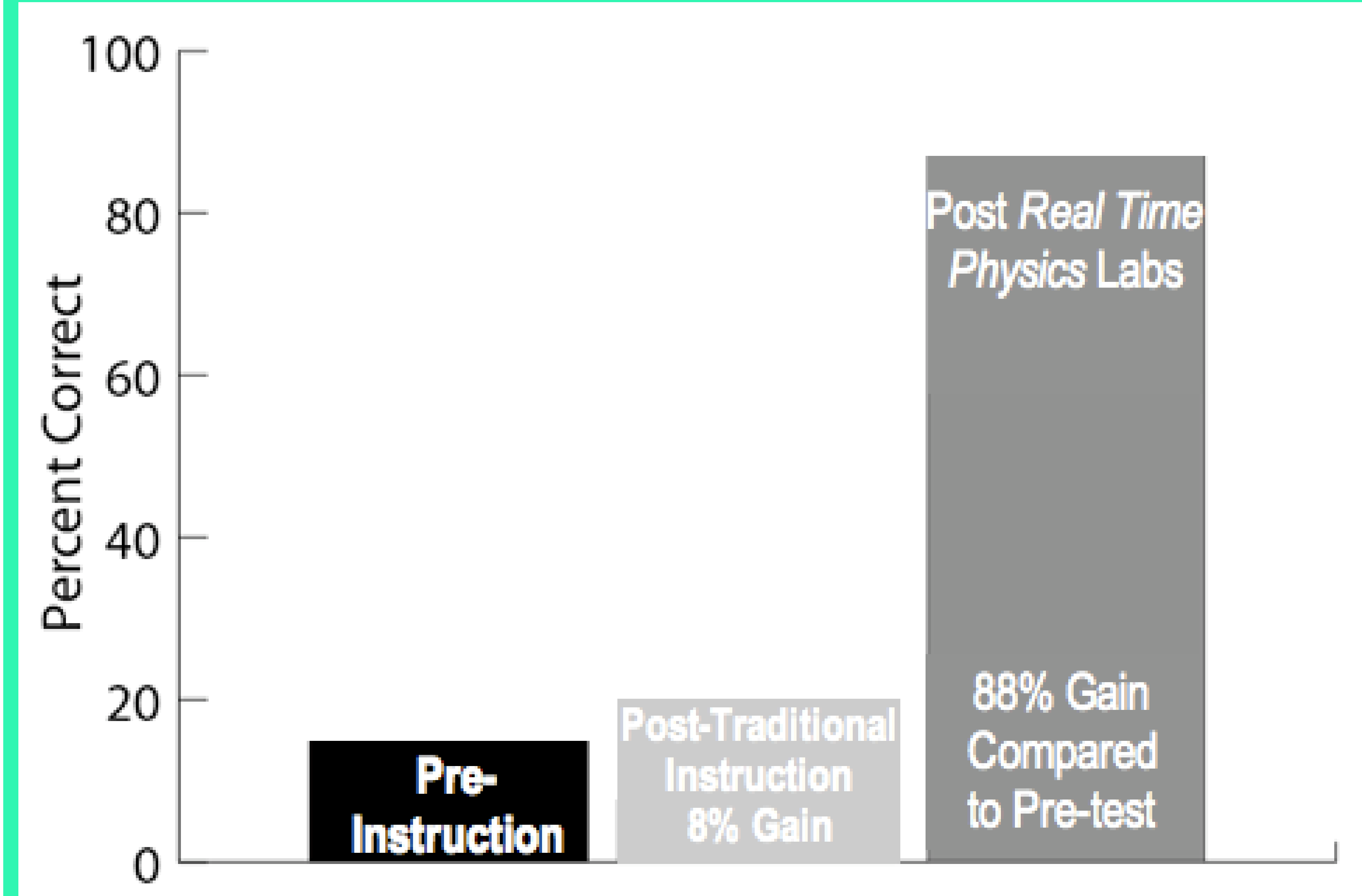
MODULE 1

Mechanics

THE PHYSICS SUITE

DAVID R. SOKOLOFF
RONALD K. THORNTON
PRISCILLA W. LAWS

Do students learn concepts from *RealTime Physics* Labs?


Percent Correct
100
80
60
40
20
0
Pre-Instruction
Post-Traditional Instruction 8% Gain
Post Real Time Physics Labs
88% Gain Compared to Pre-test