Active Learning with
*Interactive Lecture Demonstrations*

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31 years of physics education research, development and dissemination.

Winner of the 2010 APS Excellence in Physics Education Award

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Thank you to:

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The Problem . . .

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.
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.

\[ \langle g \rangle = 8\% \]
“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 predictions are never graded, 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.
### 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.

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### 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 hits the floor.
### 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.
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
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.
**Image Formation 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 above.
**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?
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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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 . . .
Pre-Instruction

Post-Traditional Instruction
20% Gain from Pre
The graph shows the percentage of correct answers before and after instruction.

- Pre-Instruction: 40% correct
- Post-Traditional Instruction: 60% correct, a 20% gain from pre-
- Post-1-hour ILD sequence: 80% correct, an 80% gain from pre.

The ILD sequence significantly outperforms traditional instruction in terms of percentage of correct answers.
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.
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
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 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](http://www.wiley.com) and search RealTime physics.
Engage your students in the learning process!
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?