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Exploring Multimedia to Adapt Interactive Lecture Demonstrations (ILDs) for Home Use

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Abstract. With the need for distance learning materials thrust upon us alarmingly and suddenly by the Covid-19 pandemic, it is not unreasonable that many have fallen back on passive presentation of lectures and black/whiteboard notes using some mode of video conferencing. But is it possible to maintain some element of active learning for our introductory physics students? This paper will describe attempts to use the wealth of multimedia materials currently available (videos, simulations, photos, computer-based laboratory graphs, etc.) to adapt Interactive Lecture Demonstrations (ILDs*)* to a form that can be used by students at home. While recognizing that small-group discussions--and sharing in any way--may be difficult for many, these Home Adapted ILDs retain student predictions as an essential element in engaging students in the learning process. This paper will review the design features of ILDs, describe some of the multimedia resources that are freely available, and present some examples of Home Adapted ILDs. As we enter an uncertain future, this approach could have important applicability for pre-service and in-service teacher preparation programs, as well as for undergraduate physics students.

1. Introduction

Interactive Lecture Demonstrations (ILDs) is an active learning strategy first developed in the 1990s and designed to promote the active engagement of students in learning physics concepts from live lecture demonstrations. [1-3] Students--including those planning to be teachers--come into their first introductory physics course at the high school or college level with definite views about physics concepts (often wrong) based on their life experiences that are not changed by traditional, passive instruction. Physics Education Research (PER) has demonstrated that the vast majority of these students leave a traditionally taught course with the same (incorrect) views, and little understanding of physics concepts, regardless of the skill of the instructor. [4, 5]

In summary: *if no effort is made to engage students in the learning process, they will not learn physics concepts!* During the pandemic, we are faced with many learning environments *that are worse than traditional!* Are there ways that we can maintain active learning for our students through virtual learning? This paper describes a strategy adapted from ILDs that students can use online, at home, Home-Adapted Interactive Lecture Demonstrations.

2. In-class Interactive Lecture Demonstrations (ILDs)

Active learning environments like ILDs have the following characteristics. (1) The instructor's role is as a guide—not as the authority. (2) Students construct knowledge from observations of the physical world as much as possible. (3) A learning cycle of prediction/observation/comparison is used--challenging students' beliefs. (4) Collaboration with peers is encouraged. (5) Laboratory work is often used to learn basic concepts. (6) PER-validated, active learning materials are used as components of the course.

Students generally enjoy watching traditional lecture demonstrations, so does that mean that they are engaged by and learn from them? Research has shown that unless a special effort is made to engage students (e.g., by asking them to make predictions about the outcome of the demonstration), the majority of students cannot even correctly describe the result of a demonstration they experience in lecture after class. [6]

In-class ILDs are designed to engage students in the learning process as they observe and think critically about lecture demonstrations. Sequences of *single*-concept demonstrations are presented using an eight-step procedure. The left side of Table 1 lists the steps.

Table 1. The steps of the In-Class and Home Adapted ILD procedures

Steps of In-Class ILDs	**Steps of Home Adapted ILDs**
1. Describe the demonstration and do it for the class without displaying the results. 2. Ask students to record individual predictions on a Prediction Sheet. (Students are assured that predictions are not graded right or wrong, although a small amount of credit might be awarded for attendance on days that ILDs are carried out in lecture.) 3. Have the class engage in small group discussions. 4. Elicit common student predictions from the whole class. 5. Ask students to record their final predictions on the Prediction Sheet (which will be collected at the end of lecture). 6. Carry out the demonstration and display the results in an understandable way. 7. Ask for a few student volunteers to describe the results and discuss them in the context of the demonstration. 8. If appropriate, ask for a few student volunteers to discuss analogous physical situations with different "surface" features, or describe an application of the illustrated concept. This procedure is followed for each of the demonstrations in the sequence. Students may fill out a Results Sheet as a record to take home with them.	1. Student downloads the Prediction Sheet (a Word document). 2. Student reads written description of the demonstration, and may view a photo, sketch or video of the apparatus. 3. Student records individual predictions on the Prediction Sheet. 4. *Only after recording predictions*, student views the demonstration as photo(s), video(s), or simulation(s) and observes the results. 5. Student describes the results on the Prediction Sheet, compares it with predictions and often answers probing questions that guide critical thinking about the results. (The instructor may choose to have student send in the filled-out prediction sheet.) This procedure is followed for each of the demonstrations in the sequence. There is no Results Sheet, but student may keep a record on a sheet of paper.

ILDs are designed to introduce or review the most important concepts to be learned in the course. In a typical course, one lecture a week might be devoted to ILDs. Once students have mastered these concepts, other lectures can build upon this understanding. ILDs have also been used in conjunction with laboratories to introduce students to the concepts to be explored and to the apparatus that they will use, before beginning lab work.

Using the ILD procedure with carefully designed ILD sequences has been demonstrated to improve students' understanding of physics concepts. [1,3] Complete written materials (prediction and results sheets) for ILDs in 28 different topic areas from the introductory calculus-based or algebra-based physics course are available in the book, *Interactive Lecture Demonstrations*, published by Wiley. [2] The book also contains background information on the origins of ILDs, teachers' guides on each of the sequences, and teacher preparation notes to aid with presentations in class.

3. Home Adapted Interactive Lecture Demonstrations (ILDs)

When in March, 2020 it became apparent that we were experiencing a pandemic from Covid-19 that would severely limit students' in-class experiences around the world for an unknown period of time, the author began a project to adapt the available ILD sequences for use by students at home, online. This Home Adapted ILD project [7] was based on the following design principles. (1) The ILDs are largely based on in-class ones in the ILD book. [2] (2) As with the in-class ILDs, they are designed to introduce concepts or review or clarify them. (3) They are envisioned to be one of a number of at-home components of a course. (4) Since many faculty users might have little experience with the features of online platforms like Zoom [8], the ILDs envision students working alone online, with no requirement of collaboration through group work (although individual faculty could choose to add such features). (5) In place of live demonstrations, the Home Adapted ILDs make use of available multimedia (photos, videos, graphs, and simulations--e.g., PhETs [9], Physlets [10], etc.) for students' experimental observations.

These considerations led to a modification of the eight-step in-class ILD procedure. The right side of Table 1 lists the revised five steps. Small group discussions and sharing of ideas with the entire class are dropped, while predictions are retained to engage the students' attention and critical thinking.

Table 2 contains a list of the 26 sequences of Home Adapted ILDs that have been developed. The remainder of this paper describes some examples from these, and how the available multimedia resources were incorporated in them in place of live demonstrations.

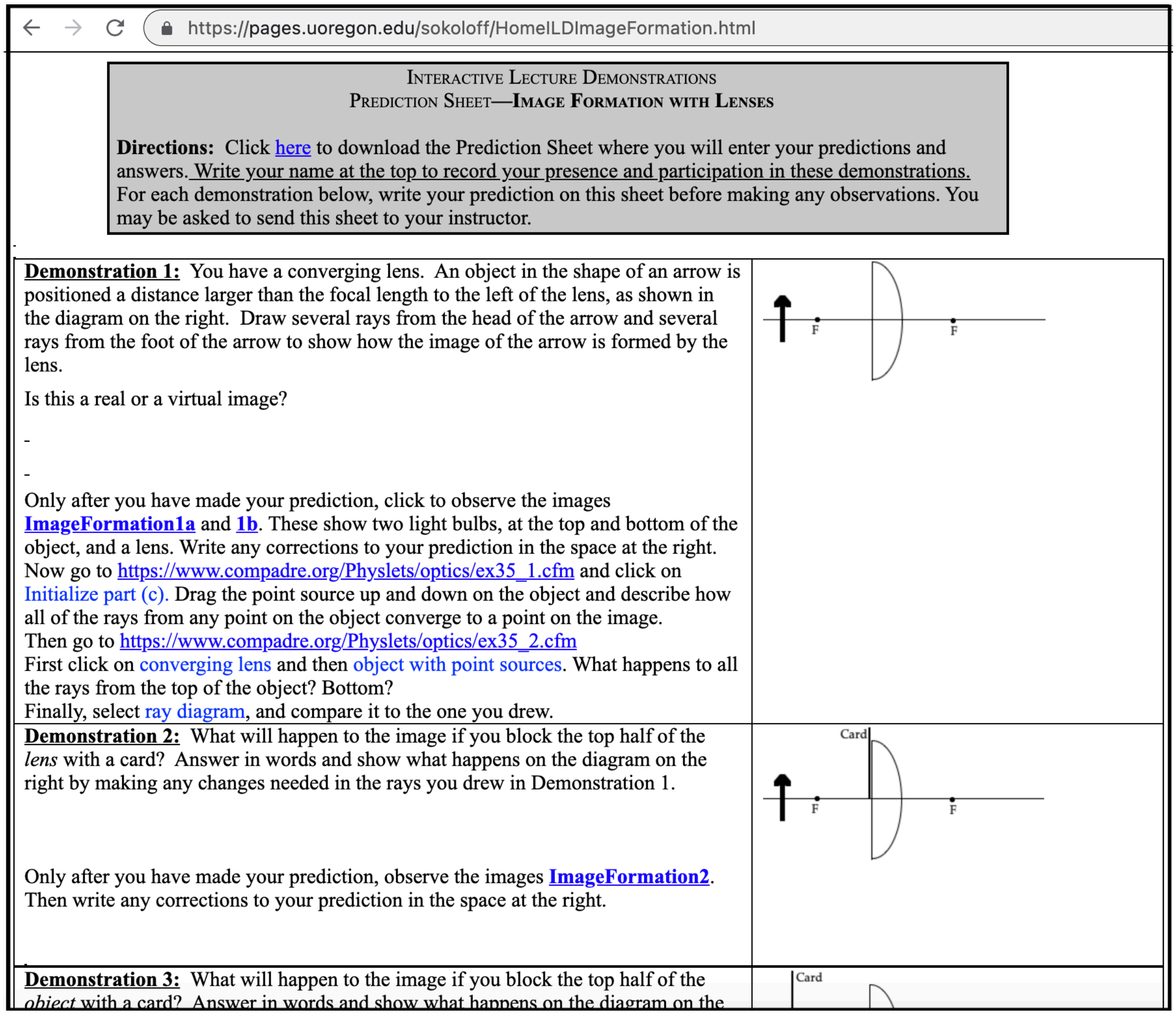
Table 2. The 26 Home Adapted ILD sequences.

1. Kinematics 1-Human Motion	14. Magnetic Forces
2. Kinematics 2-Changing Motion	15. Electromagnetic Induction and Faraday's and Lenz's Laws
3. Force and Motion-Newton's 1st and 2nd Laws	16. Reflection and Refraction
4. Force and Motion-Newton's 3rd Law	17. Image Formation with Lenses
5. Vectors	18. Polarized Light
6. Two-Dimensional Motion: Projectile Motion	19. Interference of Light
7. Kinetic and Potential Energy	20. Diffraction of Light
8. Momentum	21. Simple Harmonic Motion
9. Rotational Motion	22. Sound
10. Electrostatic Field, Force and Potential	23. Introduction to Heat and Temperature
11. Introduction to DC Circuits	24. Specific Heat
12. Current in Series and Parallel Circuits	25. Phase Change
13. RC Circuits	26. Heat Engine

4. Image Formation with Lenses Home Adapted ILDs

The "Image Formation with Lenses" Home Adapted ILDs are based on the original in-class ILDs of the same name. [2, 3] They deal with the real image formed by a converging lens, the representation of this process with a ray diagram, and the effect on the image of various changes in the experiment, e.g., blocking half of the lens, blocking half of the object, removing the lens, etc. Figure 1 shows a screenshot of the webpage for these ILDs.

Note that students first download the Prediction Sheet for these ILDs by clicking in the Directions box. They are then presented with a scenario of an object outside the focal point of a converging lens and asked to draw a ray diagram. After they have completed their diagram, they can click on two links to see photos of the experimental apparatus--consisting of two light bulbs (point sources) and an acrylic lens. Figures 2 (A) and (B) show the photos viewable at these two links, first with the light bulbs off and then with them illuminated.



https://pages.uoregon.edu/sokoloff/HomeILDImageFormation.html

INTERACTIVE LECTURE DEMONSTRATIONS
PREDICTION SHEET—IMAGE FORMATION WITH LENSES

Directions: Click here to download the Prediction Sheet where you will enter your predictions and answers. Write your name at the top to record your presence and participation in these demonstrations. For each demonstration below, write your prediction on this sheet before making any observations. You may be asked to send this sheet to your instructor.

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?

Only after you have made your prediction, click to observe the images **ImageFormation1a** and **1b**. These show two light bulbs, at the top and bottom of the object, and a lens. Write any corrections to your prediction in the space at the right. Now go to https://www.compadre.org/Physlets/optics/ex35_1.cfm and click on Initialize part (c). Drag the point source up and down on the object and describe how all of the rays from any point on the object converge to a point on the image. Then go to https://www.compadre.org/Physlets/optics/ex35_2.cfm First click on converging lens and then object with point sources. What happens to all the rays from the top of the object? Bottom? Finally, select ray diagram, and compare it to the one you drew.

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.

Only after you have made your prediction, observe the images **ImageFormation2**. Then write any corrections to your prediction in the space at the right.

Demonstration 3: What will happen to the image if you block the top half of the *object* with a card? Answer in words and show what happens on the diagram on the

Fig. 1: Screenshot of portion of the webpage for the "Image Formation with Lenses" Home Adapted ILDs.

To complete Demonstration 1, there are two links to parts of the Physlet "Lenses" [11], helping the students to visualize the infinite number of rays (cone of light) that emanate from each point on the object and to compare their ray diagram to a correctly drawn one. As can be seen in Figure 1, Demonstration 2 explores what will happen if the top half of the lens is blocked by a card. This demonstration in its in-class form (along with the ones that follow) has been demonstrated to help students understand the consequences of cones of light from a point source, rather than thinking of a small number of discrete rays. [3]

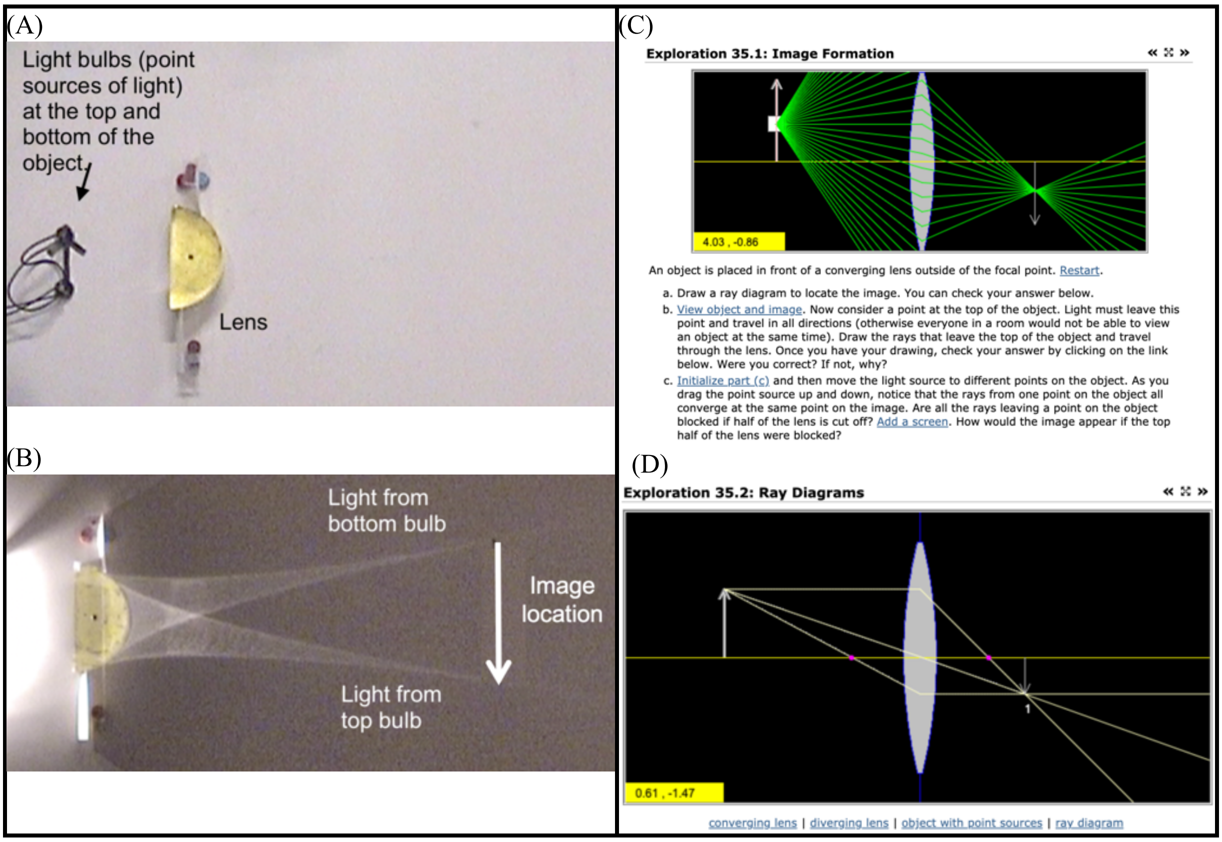


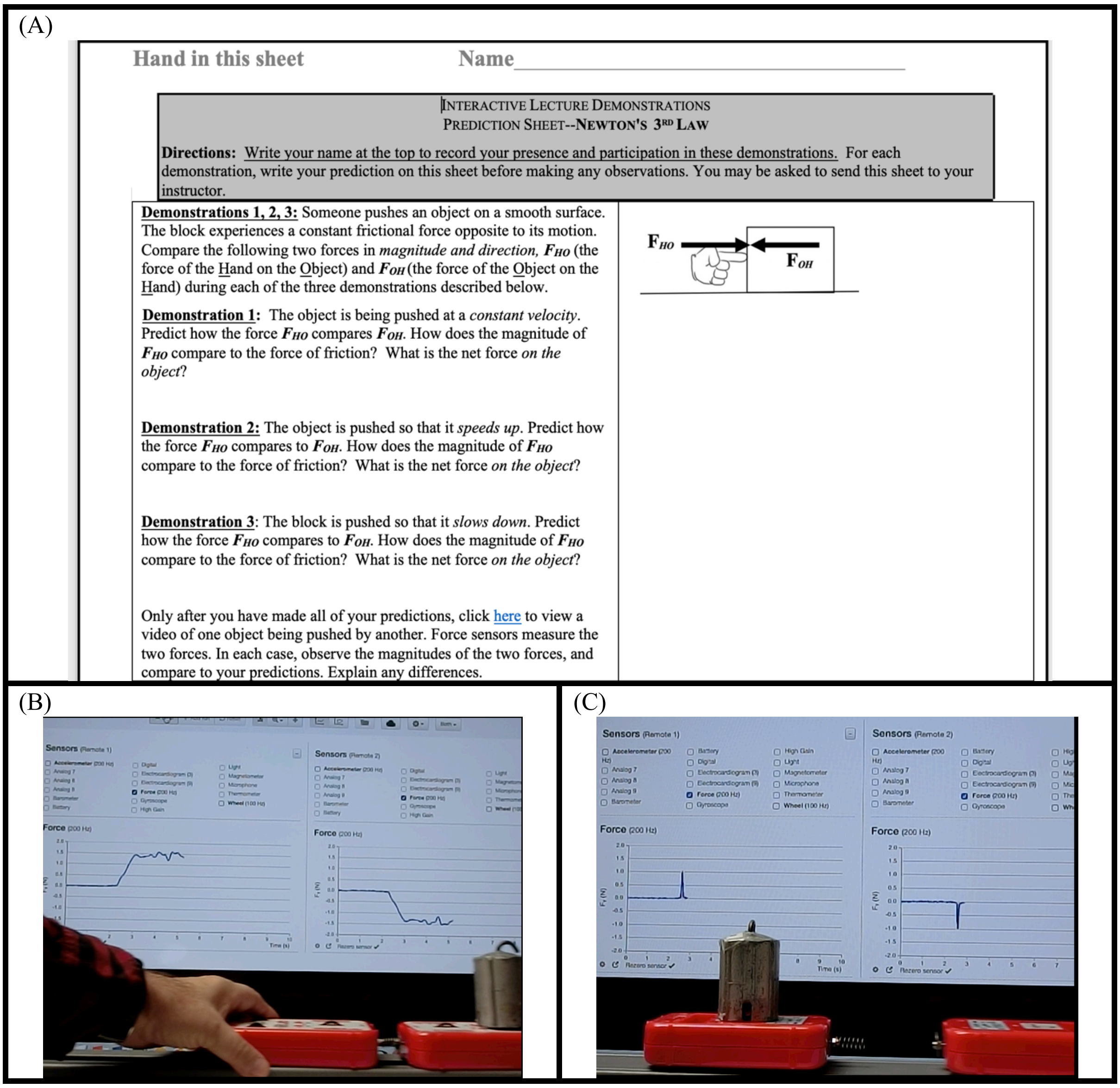
Figure 2. Images from the Home Adapted ILDs "Image Formation with Lenses" Demonstration 1. (A) Experimental apparatus. (B) Formation of real image. (C) Simulation of multiple rays with movable point source on the object from the Physlet "Lenses." (D) Ray diagram from the Physlet "Lenses."

5. Force and Motion-Newton's 3rd Law Home Adapted ILDs

The "Force and Motion-Newton's 3rd Law" Home Adapted ILDs are again based on the original in-class ILDs. [2] They deal with (1) identifying action-reaction pairs of forces and (2) establishing through a number of scenarios exactly what Newton's 3rd Law means, namely that these pairs are always equal in magnitude and opposite in direction. The experiments make use of two force sensors mounted on carts that interact with each other in various ways. Videos simultaneously display the motions of the carts and the force vs. time graphs. IOLab smart carts [12] were used to create the videos, although any computer-based laboratory system and carts could be used. [13, 14]

Figure 3 (A) shows an excerpt from the downloadable Prediction Sheet. Students are first asked to make predictions for Demonstrations 1-3 in which a heavier cart is pushed by another, first speeding up, then moving at a steady speed and finally slowing down to a stop. Figure 3 (B) shows the final frame of the video of this demonstration. It is clear from the force-time graphs that the two forces are equal and opposite during all three parts of the carts' motion. Demonstrations 4-8 involve different collisions between the two carts. In each case, students are asked to predict the forces before observing the video. Figure 3 (C) shows a frame from the video for Demonstration 6, an asymmetrical collision between heavy and light carts, with the heavy cart initially moving and the lighter one at rest. Having been engaged by the predictions, the observations convince the vast majority of students that action-reaction forces are always equal and opposite.

The in-class form of these ILDs has been demonstrated through pre and post-testing to significantly improve students' understanding of these concepts. [1]


(A)

Hand in this sheet Name________________

INTERACTIVE LECTURE DEMONSTRATIONS
PREDICTION SHEET--NEWTON'S 3RD LAW

Directions: Write your name at the top to record your presence and participation in these demonstrations. For each demonstration, write your prediction on this sheet before making any observations. You may be asked to send this sheet to your instructor.

Demonstrations 1, 2, 3: Someone pushes an object on a smooth surface. The block experiences a constant frictional force opposite to its motion. Compare the following two forces in *magnitude and direction,* F_{HO} (the force of the Hand on the Object) and F_{OH} (the force of the Object on the Hand) during each of the three demonstrations described below.

Demonstration 1: The object is being pushed at a *constant velocity*. Predict how the force F_{HO} compares F_{OH}. How does the magnitude of F_{HO} compare to the force of friction? What is the net force *on the object*?

Demonstration 2: The object is pushed so that it *speeds up*. Predict how the force F_{HO} compares to F_{OH}. How does the magnitude of F_{HO} compare to the force of friction? What is the net force *on the object*?

Demonstration 3: The block is pushed so that it *slows down*. Predict how the force F_{HO} compares to F_{OH}. How does the magnitude of F_{HO} compare to the force of friction? What is the net force *on the object*?

Only after you have made all of your predictions, click here to view a video of one object being pushed by another. Force sensors measure the two forces. In each case, observe the magnitudes of the two forces, and compare to your predictions. Explain any differences.

Fig. 3. (A) Excerpt from Prediction Sheet for the Home Adapted ILD sequence "Force and Motion-Newton's 3rd Law." (B) Force-time graphs of action-reaction pair of forces when a heavy IOLab is pushed along by a lighter one (Demonstrations 1-3). (C) Force time graphs for a heavier IOLab colliding with a lighter one (Demonstration 6).

6. Introduction to DC Circuits Home Adapted ILDs

Adapted from the original in-class ILDs of the same name, "Introduction to DC Circuits" introduces students to basic ideas about ohm's law, ohmic and no-ohmic devices, series and parallel connections and the basic relationships between currents and voltages in these. Figure 4 (A) shows an excerpt from the downloadable Prediction Sheet for these demonstrations.

To facilitate student observations at home with simple circuits, we make use of the PhET "Circuit Construction Kit." [15] This simulation enables students to construct simple DC circuits of their choice by dragging circuit elements (bulbs, wires, batteries, switches, meters, etc.) into the workspace, and observing the resulting currents and voltages. Figure 4 (B) shows a screen shot illustrating the observations for Demonstration 5, comparing the currents flowing through two light bulbs of different resistances connected in series. Before an active intervention like this, the majority of students in an introductory course would predict that current is "used up" flowing through a light bulb, and therefore, the current flowing through the right bulb would be larger than that through the left.

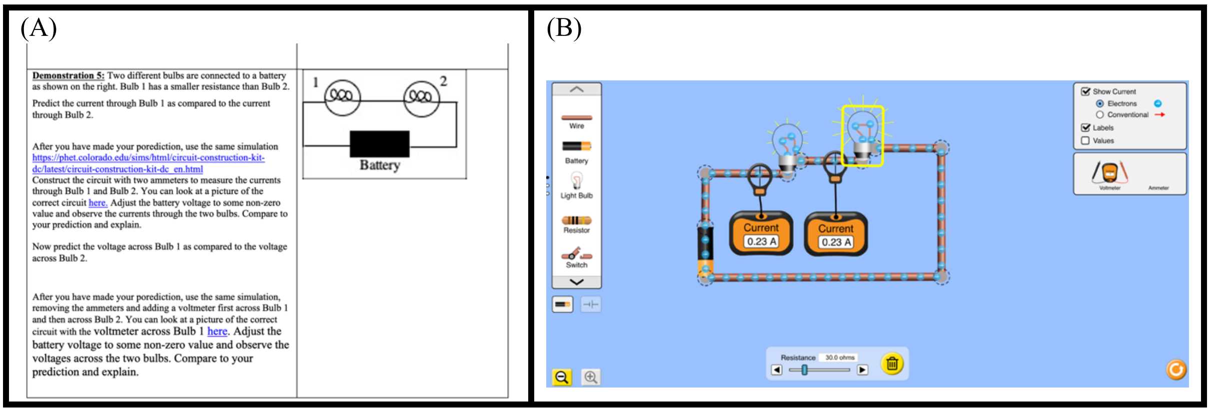


Figure 4 (A) Excerpt from the Prediction Sheet used by students for the Home-Adapted ILDs "Introduction to DC Circuits." (B) Simple series DC circuit with two light bulbs of different resistances connected in series with a battery, set up in the PhET "Circuit Constriction Kit."

7. Introduction to Heat and Temperature Home Adapted ILDs

As a last example of Home Adapted ILDs, Figure 5(A) shows an excerpt from the downloadable Prediction Sheet for "Introduction to Heat and Temperature." This sequence of ILDs--like the original in-class ones--is designed to intervene with student confusion about the concepts of "heat" and "temperature." A number of demonstrations are set up to look at situations in which it is clear that temperature change and heat flow are related, but decidedly not the same thing.

In Demonstrations 1 and 2 (the latter illustrated in Figure 5) a hot piece of metal cools to room temperature under two scenarios: (1) coming to equilibrium in the air and (2) coming to equilibrium in room-temperature water. In Demonstration 2 the temperatures are measured by two Vernier [13] temperature sensors, one in the water and the other embedded in a small brass cylinder. The data are displayed with Vernier LoggerPro software, and the entire scenario--both experiment and data display--are recorded on a video. Figure 5(B) shows a frame from this video. After comparing the observed results to their predictions, the students are asked to compare the results to the ones when the brass cools in air.

8. Conclusions

ILDs were first developed 30 years ago as one strategy to make a large (or small) lecture class a more active learning environment. Research evidence has demonstrated the effectiveness of this classroom strategy. [1, 3] The availability of vast multimedia resources has enabled the author to develop Home Adapted ILDs in which these resources substituted for live demonstrations allow students to carry out the prediction, observation and comparison components of ILDs. Using these resources, Home Adapted ILDs in most topic areas from the introductory physics course have been developed.

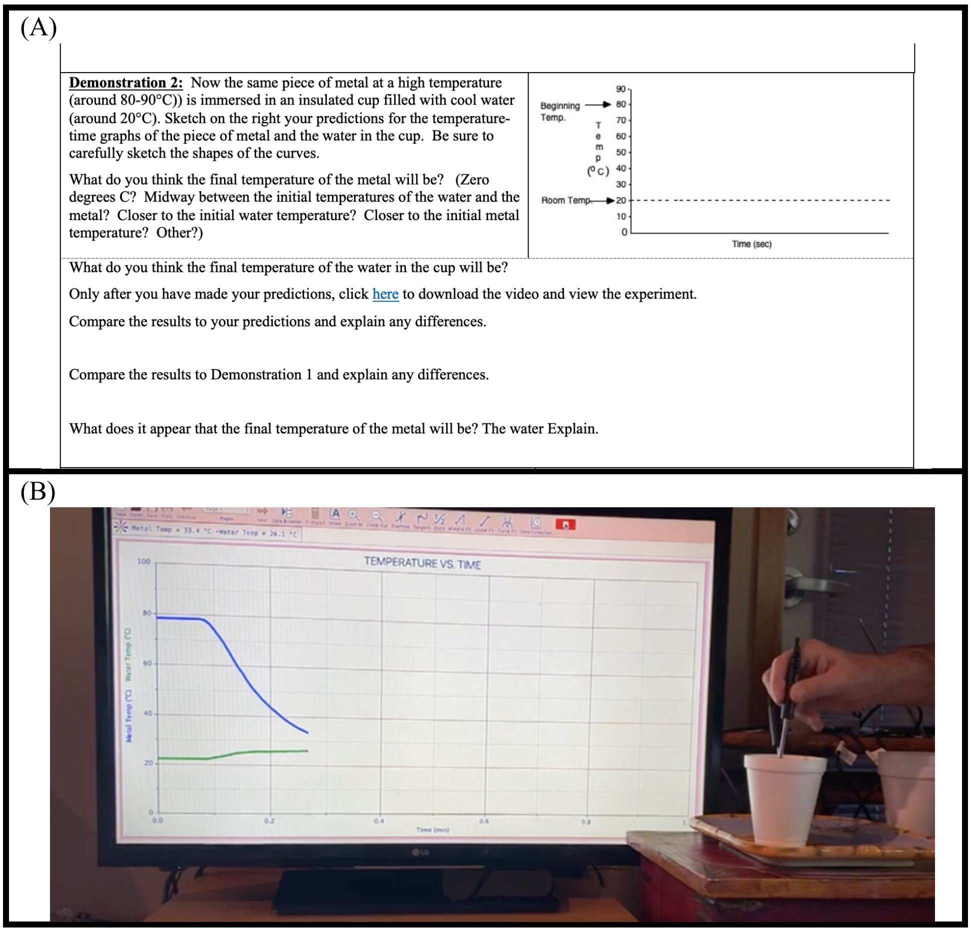


Figure. 5: (A) Excerpt from downloadable Prediction Sheet for Home Adapted ILDs "Introduction to Heat and Temperature" showing Demonstration 2. (B) Frame from a video showing the experiment and the evolution of graphs of the temperatures of a hot piece of brass (blue) immersed in cold water (green) as they come to thermal equilibrium.

Because the Home Adapted ILDs were developed under the duress caused by the Covid-19 pandemic beginning in March, 2020, it has not been possible to organize research studies on their effectiveness. If they are to be used in the future, studies using pre- and post-testing should be carried out--like those carried out for in-class ILDs. [1, 3] However, it is speculated that retention of the prediction, observation and comparison steps should result in robust conceptual learning.

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