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Web-delivered interactive lecture demonstrations: Creating an active science learning environment over the internet

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Summary. — Interactive Lecture Demonstrations (*ILDs*) are a proven, research-based strategy for significantly improving conceptual learning in large (and small) lecture classes where most physics students are taught. In some settings, up to 90% of students learn kinematics and Newton's Laws conceptually after four 50-minute *ILD*s. After a semester of good traditional instruction, the gain is typically 10 to 20%. We have adapted the pedagogically successful *ILD* procedures for internet delivery as a proof of concept. In trials of Web*ILD* delivery involving relatively small numbers of students at Tufts (60) and the University of Oregon (32), we were pleasantly surprised at the result. To prove the generality of the method we will extend this strategy to additional physics content areas and to other science disciplines. We intend to use these materials to be used for teacher education and distance learning. High schools have shown interest. Come see these techniques and see if they have any relevance to your teaching.

PACS `01.50.-i` – Educational aids.
PACS `01.50.F-` – Audio and visual aids.

1. – Introduction

In this article we will describe a project whose purpose is to extend a pedagogical procedure, *Interactive Lecture Demonstrations* (*ILDs*) [1,2], which already works well in a proven difficult learning environment, the physics lecture hall or classroom, to what is probably an even more difficult environment, the internet. Educators often compare student learning as a result of web-delivery of learning materials to traditional science courses, where research shows few students learn. To conclude from such a comparison that web-delivery is better, may not serve education. If we compare web-delivery learning results to classroom and laboratory techniques that actually result in most students understanding the materials, we are then using an authentic standard We have preliminary evidence the extension of the *Interactive Lecture Demonstrations* to internet

Fig. 1. – A screen shot showing one of eight steps in a single ILD from one of the Motion, Force, and Energy WebILD sequences. The student is viewing an introductory video of the experiment (that doesn't show actual measurements) prior to making an individual prediction (see fig. 2).

delivery (Web*ILD*s) results in student conceptual learning that is many times better than standard instruction and comparable to in-class delivery of *ILD*s([1]).

Most in-class *Interactive Lecture Demonstrations* (*ILDs*) make use of real-time data collection and display or MBL (in our case Logger*Pro* with a Lab*Pro* interface from Vernier). Each individual demonstration in a sequence of 6-8 demonstrations follows an eight-step procedure. Students are given two sheets with the demo's described—a "prediction sheet" which they hand in and a "results" sheet which they may keep.

2. – Interactive Lecture Demonstration Procedure

1) Describe the demonstration and do it for the class without MBL measurements.

2) Ask students to record individual predictions.

3) Have the class engage in small group discussions with nearest neighbors.

4) Ask each student to record final prediction on handout sheet (which will be collected).

([1]) During the workshop, after a general presentation of WEBILD, groups of two participants explored and discussed some of the most interesting WEBILD.

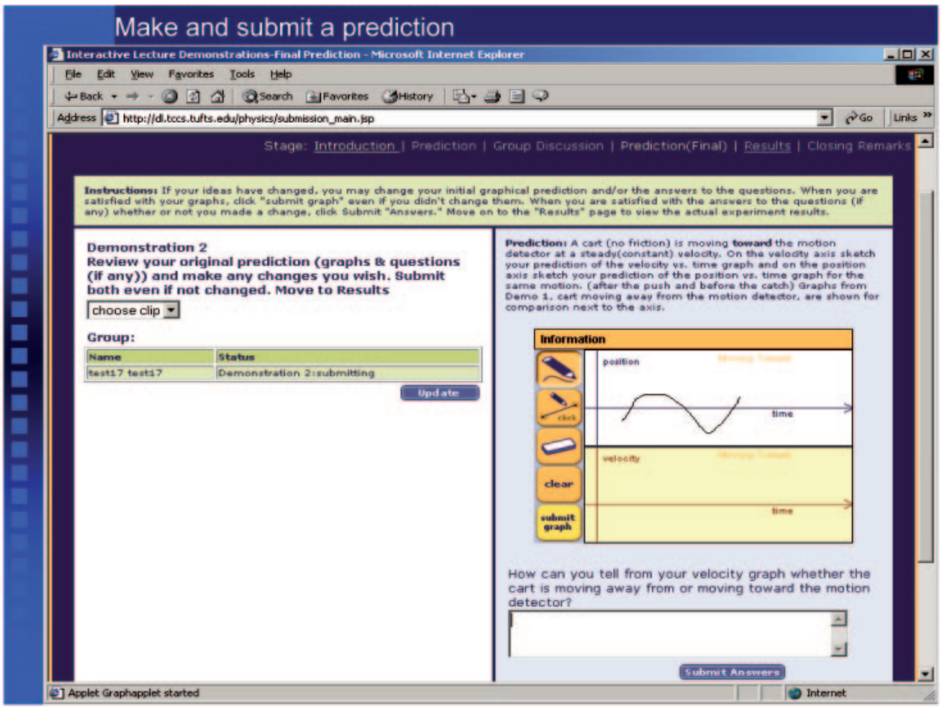

Fig. 2. – A screen shot showing one of eight steps in a single ILD from one of the Force, Motion, and Energy WebILD sequences. After viewing a video of the experiment, the student is making an individual prediction by drawing graphs and answering questions. The next step is a group discussion (see fig. 3).

5) Elicit predictions & reasoning from students.

6) Carry out the demonstration with MBL measurements displayed.

7) Ask a few students to describe the result. Then discuss results in the context of the demonstration. Ask students to fill out "results sheet" (which they keep).

8) Discuss analogous physical situations with different "surface" features. (That is, a different physical situation that is based on the same concept.)

To deliver *ILDs* over the internet we needed to development web-aware software that 1) can present in proper order the many short video sequences that replace the actual presentation of demonstrations in a classroom; 2) is able to present and replay results as graphs and data synchronously with video sequences; 3) is able to present questions and collect student responses to a data base; 4) provides mechanisms to facilitate real-time internet textual discussions of predictions and results by small groups composed of students in different physical locations; 5) allows students to draw graphs and share them with others in the group; 6) provides administrative functions for monitoring students, collecting data for evaluation, and allows *ILDs* to be constructed. We have created such software and tested it with students at Tufts and the University of Oregon. Figures 1-4 show screen shots.

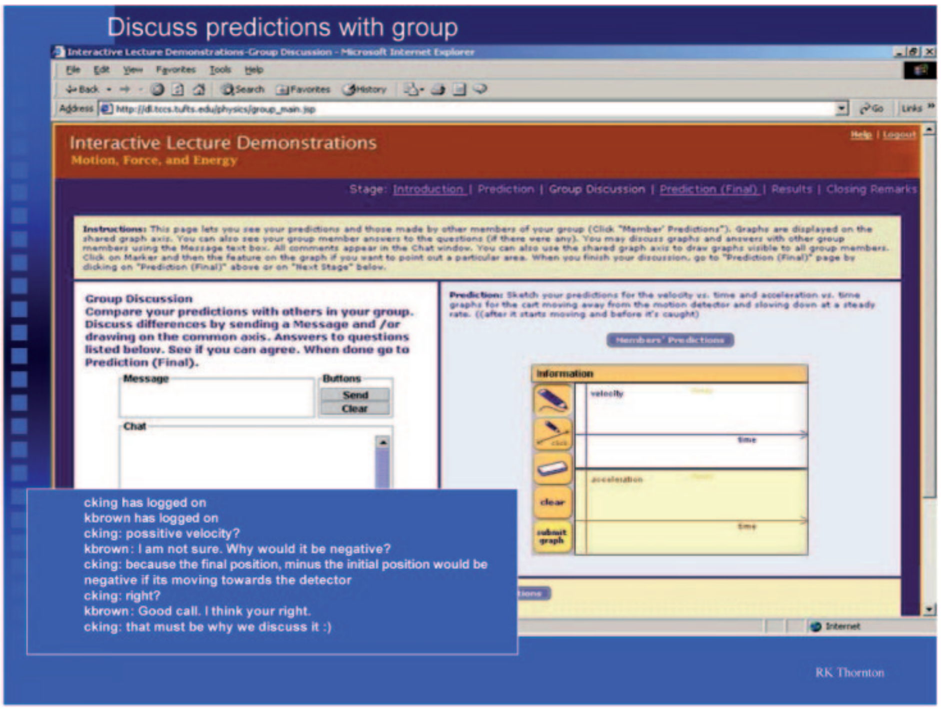

Fig. 3. – A screen shot showing one of eight steps in a single ILD from one of the Force, Motion, and Energy WebILD sequences. After the student makes an individual prediction by drawing graphs and answering questions, she discusses the prediction with her group members by using a "chat" function. An exchange is shown over-laid above. Students can see graphical predictions and question answers from group members. The next step allows students to change their original prediction if they wish.

3. – Student Testing and Learning Results (Academic Year 2002-2003)

We began testing with the software prototype with students in the introductory non-calculus physics class at Tufts University and the University of Oregon in September 2002.

At Tufts students were assigned the Third Law Sequence WebI*LD* as homework. The other three *ILD* sequences in *Motion, Force, and Energy* series were delivered in class. These *ILD* sequences teach concepts in kinematics, Newton's Laws and Energy. To do the WebI*LD* the students had to find at least one partner to collaborate with who could be on the Web at the same time (not the same place). Tufts servers delivered the *ILD* and collected the results using the prototype software. Learning results are shown in fig. 5.

We are using questions from the *Force and Motion Conceptual Evaluation (FMCE)* [3] to evaluate student learning. Figure 5 shows typical learning gains of approximately 10% in a traditional well-taught university classroom [4]. For in-class ILDs in a previous year at Tufts, the average gain for both categories was 89%. The average gain for Third Law Sequence Web*ILDs* was 72% using our first prototype software. This is better than expected with Web*ILDs* producing about 81% of the learning that in-class *ILD*s produce and about 7 times better than standard instruction.

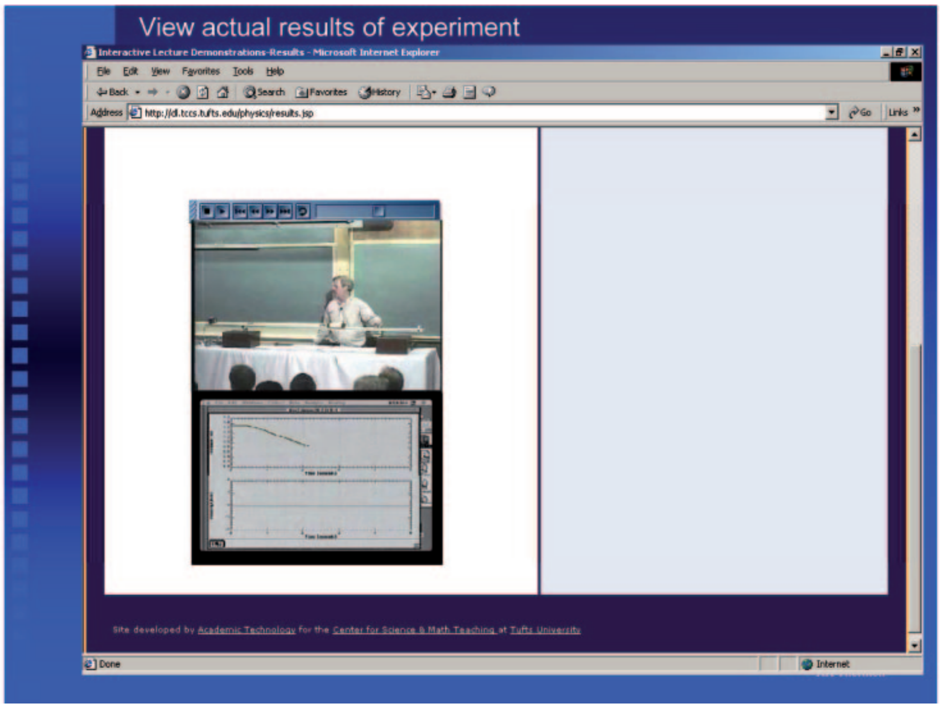

Fig. 4. – A screen shot showing one of eight steps in a single ILD from one of the Force, Motion, and Energy WebILD sequences. After the student makes a final prediction, she is allowed to view the actual results of the experiment. As the video plays the results are shown in "real-time" just as happens in the classroom using the LoggerPro software.

At the University of Oregon, we divided the students in the introductory algebra-based physics course into two groups where one group received Motion, Force and Energy *ILD*s in-class and one group received Motion, Force and Energy Web*ILDs*. (The short introductory *ILD* sequence on the kinematics of walking was given in-class to both groups since we did not have a Web version). All other instruction was the same for two groups. The groups scored similarly on the pre-test using the *FMCE*. The students taking the Web*ILDs* were scheduled for a class period so they could be supervised. The only communication with students in the groups they formed was over the Web. They were not allowed to talk to one another. The Web*ILDs* were delivered from a Tufts server.

The results of this extended test are shown in fig. 6. Again the results were more than gratifying in that the Web results are 125% better than in-class delivery and about 4.6 times better than standard instruction. However the in-class delivery showed a normalized gain of only 45% while in previous years it has been closer to 80%. The *ILD*s were delivered by the same professor in the same way. We have no explanation for the drop. The students may be changing.

We would expect an even better result for the Web*ILDs* if the students had been allowed an appropriate amount of time. They were scheduled for a 50-minute period. This is enough time for an in-class *ILD* sequence but we estimate that students require 60 to 70 minutes when they are Web-delivered due to typing and figuring out what to do. Consequently not all students finished.

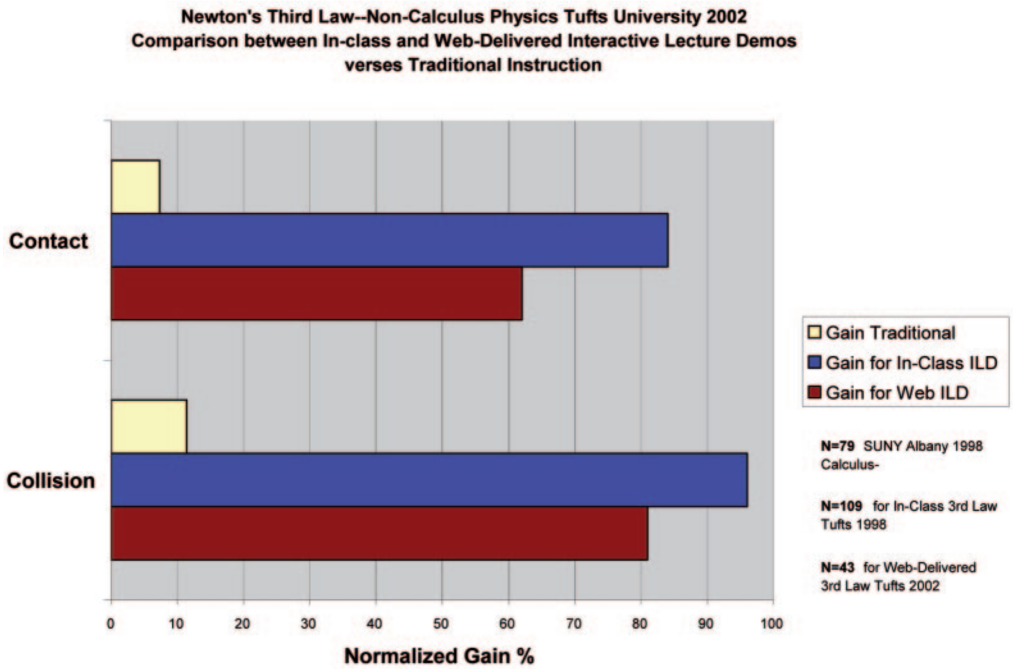

Fig. 5. – Normalized gain of students on Third Law questions (divided into collisions and contact forces) from the Force and Motion Conceptual Evaluation (FMCE). Normalized gain is the % of students who don't know a concept that learn it. The first bars show gains in a traditional Calculus-based physics course at SUNY Albany. (Gains of 10% are typical in well taught traditional courses.) The second bars show results at Tufts in a previous year for in-class delivered 3rd Law ILDs. The final bars show the result for 3rd Law WebILDs.

4. – Current and Future Plans

We have revised the student interface and are testing again at Tufts and Oregon. In the next few months there will be an opportunity to try the Web*ILDs* on-line. A link will be established at the web-site of the *Center for Science and Math Teaching*. (`ase.tufts.edu/csmt/`) There will be opportunities for testing for those who are interested.

5. – Credits

This has been funded by FIPSE of the U.S. Department of Education. Ronald Thornton of Tufts University is the Project Director and David Sokoloff of the University of Oregon is a Principle Investigator. Academic Technology at Tufts University has been responsible for the web-based software implementation.

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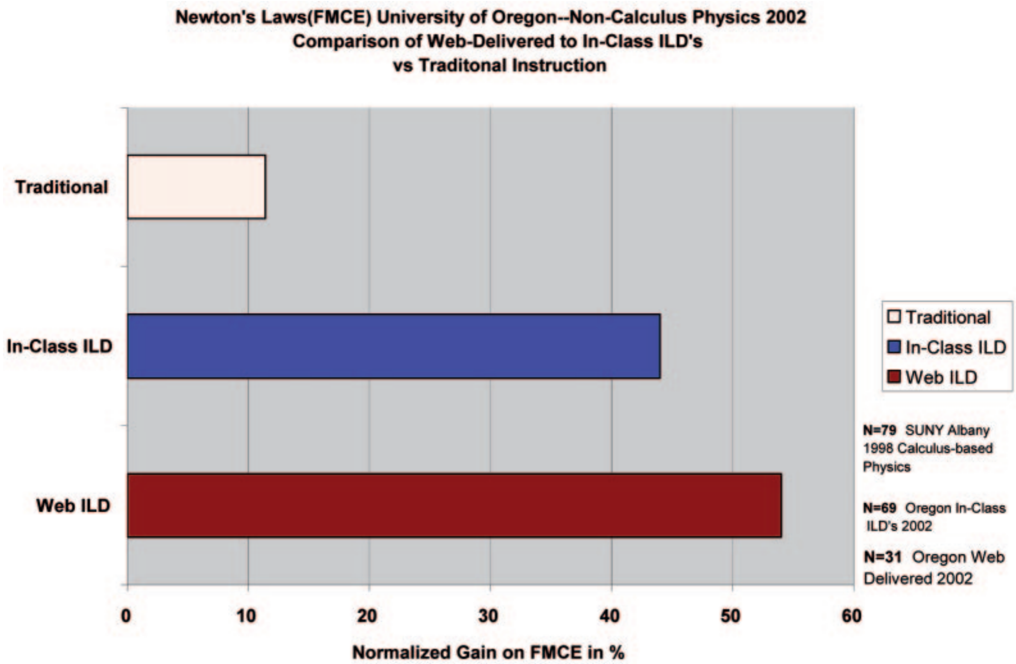

Fig. 6. – Normalized gain of students on the Force and Motion Conceptual Evaluation (FMCE). Normalized gain is the % of students who don't know a concept that learn it. The first bars show gains in a traditional Calculus-based physics course at SUNY Albany. (Gains of 10% are typical in well taught traditional courses.) The second bars show results at the University of Oregon for in-class delivered Force, Motion, and Energy ILD sequences. The final bars show the result for students who experienced the Force, Motion, and Energy WebILDs.

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