Effectiveness of Abridged Interactive Lecture Demonstrations

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Abstract

An experiment designed to investigate an abridged Interactive Lecture Demonstration (ILD)[1] protocol was performed in the Studio Physics I course[2] at Rensselaer Polytechnic Institute (RPI) during the spring of 2002. Approximately 300 students in several different sections of the course were divided into two groups. Both groups witnessed an entire Newton's Third Law ILD series. However, one group was asked for only a prediction before viewing each demonstration. The other group was prompted to engage in all eight steps of the suggested ILD procedure. A detailed discussion of the experiment, learning gains for the two groups as measured with the Force and Motion Conceptual Evaluation (FMCE), and implications for instruction are presented.

Motivation

At the Winter 2002 meeting of the American Association of Physics Teachers (AAPT), researchers from Harvard University presented data that indicted demonstrations preformed in the traditional manner (i.e. with no formal requirement of student participation) did not produce significant levels of durable learning as compared to no demonstration at all. However, when the demonstration presentation included a formal student prediction step, it produced significantly higher levels of understanding. They also found that demonstrations preceded by *only* a "prediction step" were as effective as demonstrations done using a lengthier protocol involving a student prediction, group discussion, observation, and reflection back on predictions.[3,4]

That study intrigued the authors because Interactive Lecture Demonstrations (ILDs) have been used for several years to bolster learning in the Studio Physics courses at Rensselaer. However, the fairly complex demonstration protocol, which is similar to the one Harvard researches looked at, has been an impediment to the spread of this pedagogical approach among the research-active faculty who teach the Studio Physics courses at Rensselaer. In fact, we have had two difficulties with the use of ILDs in these courses. The first is the time and the motivation on the part of instructors that is needed to execute the eight-step demonstration process. The second is an unwillingness on the part of students to volunteer their predictions for large group discussion.[2] If an abridged demonstration protocol were equally as effective as the longer counterpart, this would be an advantage for implementations in time-constrained, multiple-instructor courses like Studio Physics. In addition, this study of a simpler demonstration procedure sheds light on which aspects of the ILD procedure are the most critical in producing student learning.

Background on ILDs

Interactive Lecture Demonstrations are an instructional technique pioneered by R. K. Thornton and D.R. Sokoloff. [1] They have been developed and refined based on the findings of education research. Each ILD is a set of about six conceptually-linked demonstrations on a particular topic. ILDs often exploit the real-time data acquisition and display powers of micro-computer based laboratory (MBL) tools[1]. Several of these sets of demonstrations are commercially available, including the set on Newton's third law that is the subject of this study.

The steps currently prescribed by Thornton and Sokoloff for use during ILDs are as follows: [1,2]

1. The instructor describes and performs a demonstration without actually taking the data.
2. Students record their name and individual prediction on a *Prediction Sheet.*
3. Students engage in small group discussion about these predictions.
4. Students make any desired changes to their predictions on the prediction sheet.
5. The instructor elicits common student predictions from the class.
6. The instructor performs the demonstration, this time displaying the data or result to the entire class. Attention is called to the most important fea-

tures or outcomes, and how they relate to the physical situation.

7. Students record and discuss the results.
8. The instructor discusses analogous physical situations.

The authors of this paper are among a group of people working at diverse institutions who have had significant success in increasing student conceptual understanding through ILD use. For example, Cummings, Marx and all [2] measured the normalized student learning gain $<g>$ [5] on both the Force Concept Inventory (FCI) [6] and FMCE in the Studio Physics I course at Rensselaer during the spring of 1998. They found $<g_{FCI}> = 0.18 \pm 0.12$(s.d.) and $<g_{FMCE}> = 0.21 \pm 0.05$(s.d.) without ILD use and $<g_{FCI}> = 0.35 \pm 0.06$(s.d.) and $<g_{FMCE}> = 0.45 \pm 0.03$(s.d.) for equivalent sections in which ILDs were preformed.[2] Equally high learning gains have been consistently measured in Studio sections at Rensselaer whenever ILDs have been performed.

However, not everyone who has tried to implement ILDs has been so successful. Both Ian McFarland[7] and Michael Wittmann[8] have given AAPT conference presentations in which they reported less than satisfactory learning gains associated with ILD use. Why are some instructors more successful at implementing ILDs than others? In any given case, there may be several contributing factors. Some of the possibilities are associated with the way in which the instructor delivers the demonstrations.

An abridged demonstration protocol, if equally successful, can help to rule out some of the suspected causes of the less-than-stellar learning gains sometimes reported following ILD use. For example, suppose one found that there is no negative effect on learning gains when one completely eliminates the ILD step in which the instructor makes analogies between the demonstration and other physical situations (Step#8). In that case, we could reasonably rule out an instructor's poor or inconsistent execution of this step as the primary factor in an unsuccessful ILD implementation. (Of course, such a result can not be taken as an indication that making analogies is an extraneous part of the ILD process. Rather, this "generalization step" may be very important in facilitating learning transfer while not critical in the direct, single-concept learning that the FMCE measures.)

Experimental Design

In hope of identifying presentation factors that are *not* critical for minimally successful ILD implementation, we performed an experiment comparing the impact of an abridged ILD procedure to the impact of the full procedure as suggested by the developers. The domain of this experiment was student conceptual understanding of Newton's Third Law. Our measure of success is learning gain on third-law-related FMCE questions.

The experiment was performed in the Studio Physics course at Rensselaer during the spring of 2002. During that semester, the course was broken into nine sections meeting at different times and taught by seven different instructors. Two instructors taught two sections; the other five instructors taught one section each. Although the meeting time and instructor varied from section to section, students in all the sections followed the same syllabus and schedule, used the same textbook, did the same homework assignments, and took common exams as a single group, both at finals and during the semester. Daily lectures (presented on PowerPoint) and in-class, hands-on activities were also the same for both groups.

One of the authors (Cummings) performed the entire Newton's Third Law ILD series in all seven sections of the course. This ILD series, commercially available through Vernier Software, is comprised of six conceptually linked demonstrations of Newton's Third Law applied in various situations. For the purposes of this study, the sections of the course were divided into two groups. Classes identified here as "***long***" saw the third law series preformed using the eight-step ILD procedure described above. Classes identified as "***short***" also saw the entire series of demonstrations, but the presentation procedure was shortened to include only steps #1,2 and 6.

In considering the shortened procedure, it should be noted that although step #4 (group discussion of predictions) was officially eliminated there were students in each section who spontaneously began talking to others about their predictions. Hence, although students in the short group had not been instructed to discuss their individual predictions, students who did so on their own were not reprimanded.

There are four classes in the long category with a total of 128 students and five classes with a total of 165 students in the short category. In the case of the two instructors who taught two classes each, one of their classes was included in the long group and one was included in the short group. Assignment of a section to the long or short group was otherwise random.

To offer some objective measure of the conceptual learning gains in the two groups, the authors administered the Newton's Third Law questions from the FMCE (Questions #30-39). These questions were administered three times during the semester: on the first day of class, after 5 weeks of mechanics instruction but before the ILDs were performed, and at the end of the semester, 12 weeks after the ILD were performed.

Results and Indications

An obvious advantage of using a shortened form of the standard ILD protocol is a significant reduction in the time necessary to perform the demonstration series. The Third Law ILD series took an average of forty-five minutes to execute when the full protocol was followed. The series of demonstrations took only about twenty minutes on average with the abridged process.

In order to determine if the abridged ILD procedure had a negative impact on learning, the normalized learning gain (i.e. Hake factor) was calculated for the Newton's Third Law questions on the FMCE. The gain for a given section of the course was calculated using the average of pre-instruction scores and the average of post-instruction scores for a matched sample of students That is, only students for whom we had both pre- and post-instruction scores were included in the study and we calculated the gain on averages, rather than the average of individual's gains.

As noted above, we asked this series of questions at three points during the semester: on the first day of class (called "***pre***" in the discussion below) , after 5 weeks of activity-based mechanics instruction but before the ILD series was preformed (called "***pre-ILD***" in the discussion below) and on the last day of the semester (called "***post***" in the discussion below). In order to compare student learning at these three points in time we calculated a "pre/pre-ILD" gain , a "pre-ILD/post" gain and a "pre/post" gain.

The pre/pre-ILD gain is a measure of the impact of the five weeks of activity-based mechanics instruction. It is not a measure of any effect the ILD presentations may have had. Since students in all sections of the course engaged in nearly identical educational experiences (only their professors and class times varied), we would predict that this measure should not vary significantly between random subsets of students. As expected and shown in Table 1 below, there is no significant difference in this gain for the group of students who saw the ILD series with the full protocol (called long) as compared to the group that saw the ILD series with the abridged protocol (called short). The gains shown in Table 1 indicate that reasonably high levels of student understanding result from just the instruction students received with the Studio Physics curriculum currently employed at Rensselaer.

The pre-ILD/post gain is the most important measure for this study because it most concisely includes the impact of the ILD presentation. As the values in Table 1 indicate, eliminating steps# 3,4,5,7 and 8 from the ILD process did not have a negative impact on student learning of Newton's Third Law as measured with the subset of FMCE questions. Hence, it is unlikely that poor or inconsistent execution of any one or several of these steps is the primary reason that some ILD implementations fail. Furthermore, if instructors are willing to sacrifice the (unmeasured) pedagogical value of these steps, this study indicates that the time and effort needed to do ILDs can be reduced without negatively impacting conceptual learning. In fact, the average of the average gains for sections of the course included in the short group were slightly higher than for sections included in the long group. A t-test was run to determine if this difference in average gain was statistically significant. It is not. None of the experimental t values are significant at the 90% confidence level ($t=1.90$ $p=0.1$).

It should be noted that the pre-ILD/post gain does not just measure the impact of the ILD presentation. It also includes the impact of the additional 12 weeks of instruction. Topics covered during this time include conservation of energy and momentum, collisions, rotational motion, universal gravitation, and Coulomb's law. Several of these topics offer opportunities to spiral back to a discussion of Newton's Third Law. An estimation of the how much of the preILD/Post gain is the result of ILD implementation can be made by referring to Table 2. This table compares the gain in understanding on the third law questions for students in the fall of 2001 and students in the spring of 2002. Students in the fall of 2001 used the same curriculum as students in the spring of 2002, but they did not see the ILD presentation. Note that the Fall 2001 gain (which is without the ILDs) is consistent with the gain in the Spring of 2002 before the ILDs were preformed.

Pre/post gains are also shown in Table 1 for completeness. These gains are a measure of the result of the entire semester of instruction including the ILD presentation.

Table 1. Calculated gains and t scores for the short and long groups.
None of the experimental t values are significant at the 90% confidence level (t=1.90 p=0.1).

SHORT (N=5 classes, 165 students)	AVG. GAIN +/-S.D.	LONG (N=4 classes, 128 students)	AVG. GAIN +/-S.D.	t Experimental
Pre/Pre-ILD	68.5+/-10.1	Pre/Pre-ILD	62.1+/-8.2	1.04
Pre-ILD/Post	24.4+/-14.2	Pre-ILD/Post	13.2+/-6.9	1.44
Pre/Post	75.9+/-10.5	Pre/Post	67.4+/-5.6	1.46

Table 2. A comparison between use of only the Studio Physics curriculum (fall 2001) and use of the Studio Physics curriculum with ILDs (Spring 2002).

Avg. % Correct on 3rd Law Questions	Spring 2002	Fall 2001
Pre-Instruction	36.6	40.2
Post-Instruction	82.2	76.4
Normalized Gain	71.9	60.5

References

[1] See for example, D. Sokoloff and R. Thornton, "Using Interactive Lecture Demonstrations to Create an Active Learning Environment," Phys. Teach. **35**(10), 340-347 (1997).

[2] K. Cummings, J. Marx, R. Thornton, D. Kuhl, "Evaluating Innovation in Studio Physics", American Journal of Physics, Supplement 1 to Vol. 67, No. 7, pp S38-S45 (1999)

[3] http://mazur-www.harvard.edu/Talks/pdf_files/Talk_413.pdf

[4] Announcer for Winter 2002 meeting of the AAPT

[5] R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," Am. J. Phys. **66**(1) 64-74 (1998)

[6] D. Hestenes, M. Wells, and G. Swackhamer, "Force concept inventory," Phys. Teach. **30**(3), 141-158 (1992).

[7] Announcer for Winter 2000 meeting of the AAPT

[8] Announcer for Summer 2001 meeting of the AAPT