Interactive Lecture Demonstrations

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Introduction

PH202 Physics, a calculus based physics course, is required for all cadets at the United States Military Academy (USMA), independent of their academic field of study. Although all cadets receive a Bachelor of Science degree, most receive their degrees from liberal arts departments, such as History or English. 1 The rigorous nature of the physics course, coupled with a cadet’s perception that the course will not apply to their future, creates a very negative perception of the course. They also attempt to complete their homework without reading the textbook, and if they have success with this early in the semester, the behavior continues regardless of the increasing difficulty of the material. During the blocks of instruction covering geometrical and physical optics, the last blocks for the course, instructors traditionally find it more difficult to keep cadets interested in the material.

During a faculty workshop, I was introduced to the concept of Interactive Lecture Demonstrations (ILD). The ILD was first developed in 1991 by a team at the University of Oregon. 2 They discovered that instructors can best impart knowledge when using classroom demonstrations if they require the students to predict the result of the demonstration prior to conducting the demonstration. Their premise is that students arrive in physics courses with preconceived notions about how the world works. When demonstrations are performed in class, these preconceived notions are challenged, but after a short period of time, the students revert back to their previous understanding of the physics. 3,4 If students are required to voice their preconceived notions prior to the execution of a demonstration, they are more likely to internalize the correct physics. 5 The group conducting the claimed an increase in students understanding of conceptual material, but reported a slight decrease in problem solving abilities. 6 I adopted the methods used in their research, but incorporated problem solving aspects, due to the weight of problem solving in the USMA physics course. For the final seven lessons of the second semester physics course, ILD worksheets replaced traditional lectures. The goal of the project was to increase students’ participation in class, maintain their attention, while simultaneously increasing their understanding of the material. I convinced seven other instructors to join me for this trial, and was very pleased with the results.
Procedures

The ILD procedure followed the sequence presented in *The Physics Suite*, by David R. Sokoloff and Ronald K. Thornton. All students were presented with a handout containing various diagrams of the physics demonstrations prominently displayed in the front of the classroom. The handouts also contain enough space for the students to predict the outcome of each demonstration. The instructor conducts the lesson following a rigorous eight step process.

1. The instructor describes all of the components of the demonstration.
2. The students are required to make a prediction. I encouraged the other instructors to ensure that every cadet has made a prediction prior to conducting the demonstration.
3. The students are instructed to share their answer with the cadet next to them, and allowed to change their answer if they choose. A few different solutions are placed on the boards around the room.
4. Students are now permitted to discuss with the rest of the class, and change their answer if they desire.
5. The instructor verifies that every cadet has a prediction on their handout.
6. The instructor now performs the experiment, in a manner in which all students can observe the results.
7. If a student has a correct prediction, they describe the results to the class. If not, the instructor discusses the correct outcome with the class. The students then write the correct solution on a separate handout.
8. Finally, the instructor leads the class in a brief discussion on other real-world applications of the theory, before beginning the next demonstration. Each lesson consisted of multiple demonstrations, each one utilizing the entire eight step process.

The ILDs studied in previous classrooms focus on improving students understanding of Physics concepts. Problem solving skills are delegated to the teaching assistant during a recitation and various homework assignments. Because USMA does not have teaching assistants or recitations, I included problem solving questions in the handouts. Some of the handouts were modified from those used at other universities; while others were developed from suggest experiments presented by the manufacturer. All of the handouts contained questions covering all of the lesson objectives dictated by the course director, a third year instructor, although it quickly became obvious that 55 minutes was not enough time to complete the entire handout correctly. Instructors were instructed not to focus on completing the handout, but instead complete as much as possible using the eight step method. I designed the handouts for the lessons contained in the geometrical and physical optics blocks. When possible, physical demonstrations took precedence over simulations, although one lesson required an applet presented via the overhead projector instead of a demonstration. An example of the demonstrations were displayed for all of the instructors one day prior to their conducting the lesson, as well as a brief verbal instruction on how to best conduct the ILD. After the last Optics lesson, all of the students and instructors using the ILDs were surveyed.

Interactive Lecture Demonstrations quickly became an administratively intensive activity. Every lesson required continuous work to keep all of the instructors synchronized in their presentation of the material. Instructors in PH202 always teach the
same material for a given lesson, but special emphasis was made to encourage those using the ILDs to adhere to the eight step process. After each of the seven lessons, I informally polled the instructors about the success of the individual lesson, and issued further instructions to prevent anomalies from developing between different sections. Since each instructor participating in the activity taught four sections, I am confident that the majority of the lessons were conducted in similar fashion.

Results
Previous research of ILDs attempted to demonstrate how students increase in understanding of the concepts presented in their physics course. The various surveys and evaluations look to validate this at USMA, as well as prove the ILD lessons’ effectiveness in maintaining students’ attention, as well as increase the participation of the cadets. Their performance was evaluated through several mechanisms.

- Major graded evaluations: the average points for each student for lessons taught with ILDs were compared with the average point earned for all previous lessons.
- Cadets were surveyed on the last lesson for their impressions on the ILDs.
- Instructors were surveyed to determine if the ILDs improved the classroom atmosphere.
- Cadets were polled at random after each class to provide an intermediate assessment of the ILDs.
- The year end course feedback surveys were analyzed for a comparison of students’ attitudes compared to that of the rest of the course.

The first data set came from the other instructors who included the ILDs in their course. The responses collected after each lesson are presented with the results of the instructor surveys. Unfortunately, their overall attitude towards the ILDs was very poor. Two instructors who had previously studied about ILDs share my enthusiasm, while the others did not. They did not approve of the step by step technique of the ILD process. To properly conduct the eight step process, an entire class period was required. This left instructors very little time to conduct any additional exercises, quizzes, or other activities. Even while dedicating an entire period, many instructors did not feel that 55 minutes was enough time to cover all of the lesson objectives, and three of the instructors said that they did not cover all of the material for any given lesson. This was anticipated, as the more difficult concepts, and demonstrations that led up to those concepts, were placed early in the lesson. To compensate for the lack of time, some instructors did not see the value in using two handouts, and only used one sheet. Students in these sections left the class with messy notes, often with their initial false predictions scratched out next to the proper physics. Other instructors did not demand participation, conducting demonstrations without waiting for all of their cadets to make an initial prediction. Most likely, the value of the demonstrations was lost on those students. Another observation made by the instructors was that the cadets became frustrated during the ILD. All of the lessons were designed for a classroom full of students who prepared for the lesson by reading the assigned material and attempting the homework problems. If an instructor set a precedent of teaching every learning objective on the board, their students had become accustomed to have everything given to them. Those particular sections did not adjust
well to the change of preparation standards required of them. Most instructors did appreciate that I was taking care of their lesson plans for them. I believe that by creating all of the handouts myself, I hindered the process more than I helped it. Their comments lead me to believe that most instructors using the ILDs did not prepare for their classes as well as they might have otherwise, and did not take ownership of their lessons. Despite the negative feedback, all participating instructors reported an increased alertness in their class, and sleeping cadets became rare to nonexistent.

Looking past the inherent bias of the instructors conducting the experiment, I felt that the ILDs went well in my classroom. Compared with other instructors who randomly collected homework prior to the ILD lessons, I always graded every homework assignment throughout the semester. This set a precedent in my classroom that they must prepare for each lesson. When the ILDs were implemented, the transition was not as difficult as it was for cadets taught by other instructors. I also warned my students that the ILDs would not cover every lesson objective, but that the lesson objectives covered would explained more thoroughly. I also demanded participation by every cadet. Even though I had to stand over the shoulder of some cadets to ensure they made a prediction, it was worth it observing their reactions when the demonstration was conducted. Throughout the optics lessons, I never had a single cadet doze off in class, and even cadets who traditionally held bad attitudes towards the material displayed a more positive attitude during the ILD lessons.

Cadets leaving the classroom after an ILD lesson were briefly questioned on their perception of the new method of conducting a class. After every section, at least one cadet was questioned, and often two or three were available to discuss their impressions. No cadet approached in this manner disliked the ILDs. The most common response was that they enjoyed the change of pace. They also appreciated how the new format kept them awake. To the surprise of the instructors who disliked the ILDs, these opinions were shared by cadets in all of the other sections. The instructor who shared the greatest animosity towards the project taught PH252, an advanced and more academically rigorous version of the physics course. He shared that his students all preferred lessons taught with ILDs, and requested that he continue to use them.

When the cadet surveys were tallied at the end of the semester, the cadets who did not approve of the new method finally surfaced. During the optics lessons, 365 cadets learned the optics material through the ILDs. Over 50% of the cadets preferred the ILDs to traditional lectures, and 63% felt that the ILDs made the material easier to understand. About 55% felt that their understanding of the material improved due to the ILDs, while only 13% disagreed. Only 25% of the cadets did not enjoy the ILDs during the class, and only 17% of the cadets requested that they not be used next semester. This response was anticipated because studies have shown that students often prefer a change of pace during the semester. What I did not expect was how closely the other responses correlated to their appreciation of the ILDs. Most of the students who expressed dislike towards the ILDs asked that the entire class consist of example problems. They did not display a desire to learn the physics, but only wished to take the easiest path to a good grade. Cadets also felt that the ILDs required more effort from them during the class. “Work
“more problems” was their battle cry, rather than offering other methods to better learn the concepts. Students who preferred ILDs felt that they could visualize the material better. They also appreciated that the quality of their notes improved during lessons taught with ILDs. Some cadets shared that they entered class with questions on the reading, but before they left, all of their questions were answered through the ILDs. I believe that this is the greatest indicator of success for the ILDs. Not only were some cadets inspired to read the material, but they witnessed for themselves the integration of prior preparation with classroom study. Cadets from both groups complained of shortages in time when completing the exercises. These comments from many cadets, independent of grade or instructor, show that they had an appreciation for the method of instruction, and felt that it was worth their time.

Separating the survey results by instructor provided additional insight into the success of the ILDs. There was a significant difference in student’s responses based on instructors with different attitudes. If the instructor had a positive attitude towards the use of ILDs, their students preferred to be taught with ILDs over traditional lectures, and felt that the ILDs improved their understanding of the material. Their responses remained consistent when questioned about their attitudes towards individual lessons. Previous research has shown that skipping steps and rigorous procedures do not have measurable consequences to the student’s learning. These results demonstrate that the attitude of the instructor compensates for the differences in execution of the lessons. Further research on this topic may lead to a better understanding of why some ILD research contradicts the popular accepted understanding of their value to teaching concepts. Performance on graded examinations did not correlate to the instructor preference survey. The instructor whose students voiced the greatest dislike for the ILD’s demonstrated the greatest improvement during the last seven lessons.

The value of the ILDs was also evaluated through the average grades of the cadets in the course. Only course wide graded events were included in the evaluation, all instructor specific quizzes and homework were ignored. Examinations for which the scope spanned more than one block were divided up into their individual problems, and averages were calculated for points associated with optics and averages were calculated for points associated with all other lessons. All of the 851 cadets in the course were included in this analysis. Students taught with ILDs improved their grades during the last seven lessons by an average 5.73%, compared with 4.19% for students in other sections (figure 2). Conducting a Student’s T-test on the data, there is a 99.8% probability that the results are reproducible (figure 1). Overall, 6.51% more students increased their grades when taught with ILDs. Every instructor teaching PH202 reported an improvement in grades during the last seven lessons, but out of the 18 instructors, the greatest improvements in instructor averages came from two instructors who utilized ILDs in their classrooms, and six of the top nine average improvements were from ILD instructors. All of the results are statistically significant, and have inspired other instructors to incorporate ILDs into their courses this semester.
All of the previous results were validated by the year end feedback. Survey results from the entire course, to include cadets taught from instructors without ILDs, were analyzed along with the results from my section. Course wide, most students felt that the course was academically rigorous, and more demanding than other courses. In my section, half of the students spent more than 60 minutes preparing for class, compared with only 15% of the students from the course as a whole. My students realized that reading the textbook and completing their homework were required to learn the material. Students were also asked one thing they would like to change in the course. Many responses pertained to the ILDs, such as requests to not change the presentation style, include more lessons taught with ILDs, and that they prefer the ILD method of teaching. There were also many students who requested spending more class time working problems. Similar to the responses from the ILD survey, these students demonstrate a desire to simply pattern match their answers, not showing any motivation to learn the concepts of the course. When questioned, these same students ask their instructors to teach to the test, as if their only concern was passing the course, not understanding the Physics. This response from students has been documented during similar experiments. The feedback was mostly discarded due to the small quantity of students who share this attitude. At USMA, the number of cadets who shared a preference for the ILDs slightly outnumbers the students who requested more example problems.

During the end of year feedback survey, students were also asked to state the greatest challenge to successful performance. Most claimed that time was the greatest hindrance to their success. Similar to their responses during the in class survey, they stated that there was too much material to cover in one semester. Others stated that they did not understand the instructor. Both of these responses defend the argument that students do not desire to spend time outside of class learning the material. Most cadets anticipate that their instructor covers everything in the 55 minute class period, which is an unrealistic expectation. Students were finally asked for the most effective way they learn Physics. Several said that homework helped them the most, which shows their understanding of the relationship between the homework problems and the test questions. I expect that these responses came from the same students who requested more example problems in class. A few of the students specifically stated that ILDs were the most effective way to learn Physics.

Conclusions
With 851 students included in the survey, this might be the most comprehensive study on
the effectiveness of ILDs to date. Unlike other universities, the PH201 is taught by
instructors whose primary duty is teaching. All instructors follow the course director’s
outline, and teach the same lesson objectives at the same time. The limited flexibility of
the faculty is very advantageous to the students, as two sophomore roommates with
different instructors have the opportunity to work together on every lesson. It also
supports the credibility of this study. The extreme statistical significance of the study
also defends the validity of the results.

An unexpected result of the ILDs is the correspondence between instructors with positive
attitudes and the relative attitudes of the students in those sections. The concept of
‘finding your voice’ when teaching is critical to the success of any teaching method. In
this experiment, the voice of the author of the handouts dictated the direction of the
course. Requiring individual instructors to develop their own handouts, while still
following the course director’s lesson objectives, may have been more objective. If each
section covered the same concepts, individually tailored methods of conducting the ILD
lessons may have yielded a more consistent level of appreciation from the students.
There will always be the group of cadets looking for the path of least resistance, but they
should average out, rather than dictate the results.

A concern about the numerical data from this study has surfaced. Even though the ILDs
included computational questions, the heavy weighting of problem solving questions over
conceptual questions on every graded activity in the course limit the evaluation window
for the ILD lessons. ILD lessons are designed to improve the conceptual understanding
of the students, and the best way to evaluate the successfulness of this is through testing
conceptual questions throughout the semester. The average scores of the students mostly
represent the students understanding of the equations, but more studies are required to
determine the correlation between the students increased understanding of concepts and
their performance on problem solving questions.

Interactive Lesson Demonstrations were originally designed to make the most out of
classroom demonstrations.15,16 The demonstrations for the Optics block had not been
previously attempted by most instructors, proven as most of the equipment was still
sealed in the original packaging. Unlike the force and motion questions that ILDs were
first tested on, students did not arrive with many preconceived notions about the
execution of the experiments. Most students never considered the concepts of light
diffracting through a grating, or polarization of light upon reflection. The lack of
documentation on use of ILDs for optical science lessons leads me to believe that the
results of this experiment are mostly unrelated to previous ILD studies.

Although more studies are required to determine the appropriateness of ILDs for optics
lessons, the use of the handouts was successful for some of the instructors. Instructors
who fully desire a teaching method to work will have both the attitude and put in the
appropriate effort to ensure success. For future research, instructors will be required to
make their own handouts, and given the freedom to make modifications to the ILD
process that is best suited to their ‘voice.’
Major selection numbers for the class of 2011, found at:
http://www-internal.dean.usma.edu/staff/ord/statistics/FOSMAJ_Data/FOSMAJSelected.html


5 Ibid Milner-Bolotin.

6 Ibid Sokoloff.

7 Ibid Sokoloff.

8 Ibid Sokoloff.

9 Ibid Milner-Bolotin.


13 Ibid, Roy.


15 Ibid Sokoloff.