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Interactive Engagement Learning Strategies in an Optometry Classroom Setting

Interactive Engagement Learning Strategies in an Optometry Classroom Setting

by James J. Butler and Stephen C. Hall

I. Introduction

We teach optics to a large class of about 90 students in Pacific University's College of Optometry. Like most instructors, we worry about the effectiveness of our class. Are the students getting the most from their classroom time? How do we keep every student engaged? How do we get students to read the text before class? Is there a better way to teach? For answers, we turned to modern research about student learning. The recurring message is that successful classrooms are ones in which students are actively engaged in their learning. The Physics Education Research (PER) community has developed a number of techniques and strategies that have been shown to be successful at promoting better and more efficient learning. We used modern technology to implement two of these in our course. In one we used the Internet to deliver questions and gather responses before each class. In the other we armed our students with "clickers" and used our lecture time to promote discussion amongst our students to help them actively engage the material. We believe these changes resulted in better conceptual understanding of basic optics by our students.

In order motivate our use of PER-based teaching techniques, it is best to begin with a look at some issues involved with traditional, lecture-based classes. These classes tend to promote a passive view of learning in which the teacher transmits information directly into the students' minds through spoken and/or written material. It is implicitly assumed that this information is completely and thoroughly received by the students so that they have been "educated." In this view, students are passive participants in the process. This encourages students to come to class unprepared. Why read the textbook if the teacher is going to tell you all you need to know in class? In addition, lecture is often a one-way street, with information only going from teacher to learner. Because there is little information flowing from the learners to the teacher, it is difficult for teachers to judge what students find confusing and why. As a consequence, lecture is inefficient since it spends equal time on that which students find easy and that which they find difficult.

A great deal of research, in the fields of education, psychology and physics education, has shown that there are many problems with this view of teaching [1]. This work suggests a different view of learning, one in which knowledge is not simply transmitted, but must be constructed by the learner through social interactions (both with the teacher and other students) involving the material of interest. This view of learning suggests that in a successful class, learners are actively engaged in constructing their own knowledge. Consistent with this view, years of study by the Physics Education Research (PER) community has shown that (at least in Physics) more effective teaching is done using Interactive Engagement (IE) strategies. IE strategies involve some form of active engagement of the students, such as studio style classes [2], prediction-observation activities [3], peer instruction [4] or small-group tutorials [5].

Some of the evidence for this view is provided by conceptual diagnostic exams developed by the PER community that provide objective assessment tools. For example, the Force Concept Inventory tests basic understanding of forces, and can be used to evaluate introductory physics classes [6]. These instruments are usually multiple-choice exams that tend to emphasize conceptual understanding, require little calculation, and are given pre- and post-instruction. One of the most important uses of the diagnostic exams is as a tool to assess the impact of a new curriculum idea or an innovative pedagogy.

To compare students whose different initial backgrounds result indifferent pre-test scores, one calculates the normalized gain $\langle g \rangle$=(post-test score - pre-test score)/(max possible score - pre-test score) which represents the fraction of possible improvement achieved.

One of the most striking results to come from the use of concept exams is the comparison of traditional, lecture-based instruction to "interactive engagement" (IE) instruction.

Figure 1 shows the results of one such study by Redish et. al., comparing standard lecture-based instruction classes to ones that regularly incorporate an IE activity [7]. As seen in the figure, the average gain in traditional classes was around 0.20. This means that students only improved their conceptual understanding by 20percent in these classes. On the other hand, the average gain in IE classes was between 0.35 and 0.45. This data clearly shows the advantage of IE strategies were that (on average) students improve their conceptual understanding by roughly twice as much as traditional lecture. More detailed analysis by the PER community has been done that shows this trend is widespread, across class size, school type and other factors [8]. In fact, this result is so well accepted that an average normalized gain of 0.4 on a suitable diagnostic exam has been taken as the benchmark to determine if IE strategies have been successfully implemented in a class. These results from the PER community provide a strong motivation for us to incorporate IE activities into our classes.

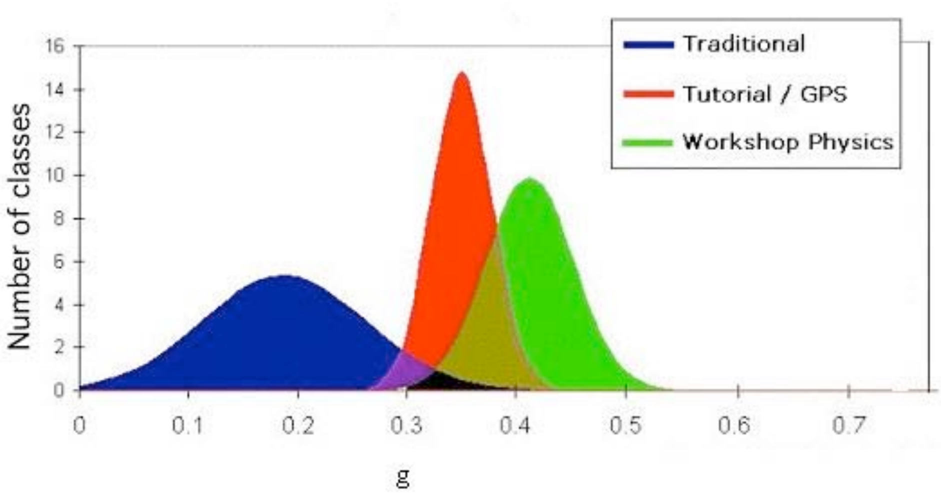

Figure 1: Results of study by Redish et. al. [7] comparing average student gains in classes with different learning styles. Plotted is the fractional gain achieved on the FCI in three types of classes: traditional, moderate active

engagement (tutorial/group problem solving), and strong active engagement (early adopters of workshop physics). Histograms are constructed for each group and fit with a Gaussian, which is then normalized.

II. Our Optics Course

We implemented IE teaching strategies in our OPT 501/502(Geometric and Physical Optics) class, which is a one-year, introductory optics sequence taught in the College of Optometry and taken by all first year optometry graduate students. Typical enrollment is about 90 students per semester. Each student in the College of Optometry is required to have a laptop, and the classroom is equipped with a wireless network and a computer projection system. There are three (Fall semester) or two (Spring semester) 55 minute class periods each week, as well as a weekly 2 hour lab period. There are daily readings from the required text and the instructors' notes are provided electronically before class. Homework problems from the text are suggested by not graded. There are two or three exams during the semester as well as a cumulative final exam. The exams consisted of both multiple-choice and worked out problems. The authors co-taught the course during the 2007-08 academic year, generally alternating classes.

III. Pedagogical Techniques: Peer Instruction and Just in Time Teaching

We implemented two pedagogical techniques to create an interactively engaged classroom: Peer Instruction (PI), implemented by a Personal Response System, and Just in Time Teaching (JiTT). Both are well-established techniques developed by Physics Education Researchers.

Peer Instruction is a technique to get students to teach each other, recognizing that some of the best learning occurs when you must explain your understanding to someone else. This technique is particularly useful for promoting IE in large classroom environments. We use the following PI cycle. We present the students with a conceptual question and ask them to answer on their own without talking with their classmates. We collect their answers and display the results to the class without indicating which answer is correct. Unless a large percent of the students (more than 80 percent) answer correctly, we ask the students to find neighbors who disagree with their choice and discuss their reasoning. After a short discussion period (2-3 minutes) we ask the students to answer the question again and we display the results once more. Typically, a greater number of students will have selected the correct answer, and in fact in most cases the correct answer will be selected by greater than 80 percent of the students. If this is not the case, we take the opportunity to provide more instruction on the topic. This process allows students to organize their thoughts and create a coherent argument about the subject, and has been shown to reinforce the conceptual understanding of physics [4]. In a typical 55-minute class session, we spend about 15-20 minutes lecturing to highlight the most important concepts or particularly subtle points from the reading. The rest of the class time is spent on PI questions or having the students work sample problems.

To collect answers quickly and accurately from 90 students we used a Personal Response System (PRS), or "clickers". Clickers are handheld devices that allow students to transmit their answers to the instructor's computer where they may be displayed and stored for future use. Older PRS systems used IR transmitters while newer ones use RF transmitters, which can transmit more data faster. We used RF transmitters from Interwrite [9] shown in Figure 2. The devices allow students to answer a wide range of question types including True/False, multiple choice, numerical answer and multiple selection. The screen provides students feedback when their answer has been received. Each clicker costs about 30 dollars and the RF receiver that is connected to the instructor's computer costs about 100 dollars. Free software is provided to run the system and display the results.

Figure 2: The "clicker", part of the PRS system from Interwrite [9] used in the study.

Figure 3 shows an example of a question used in a PI cycle. Figure 4 shows the student responses before and after discussion, showing the dramatic improvement described above. Figure 5 shows another example. In this case there are actually three PI questions, one for each numbered incident light ray. Figure 6 shows the student responses for ray 1 and ray 2. In each case, a large fraction of the students chose the correct answer the first time. When this happens, we do not complete the PI cycle by having the students discuss their answer. In the case of ray 3 however, the first set of answers show greater student confusion, as shown in Figure 7, and so the full PI cycle was done. After student discussion, the correct answer was selected by a large fraction of the students.

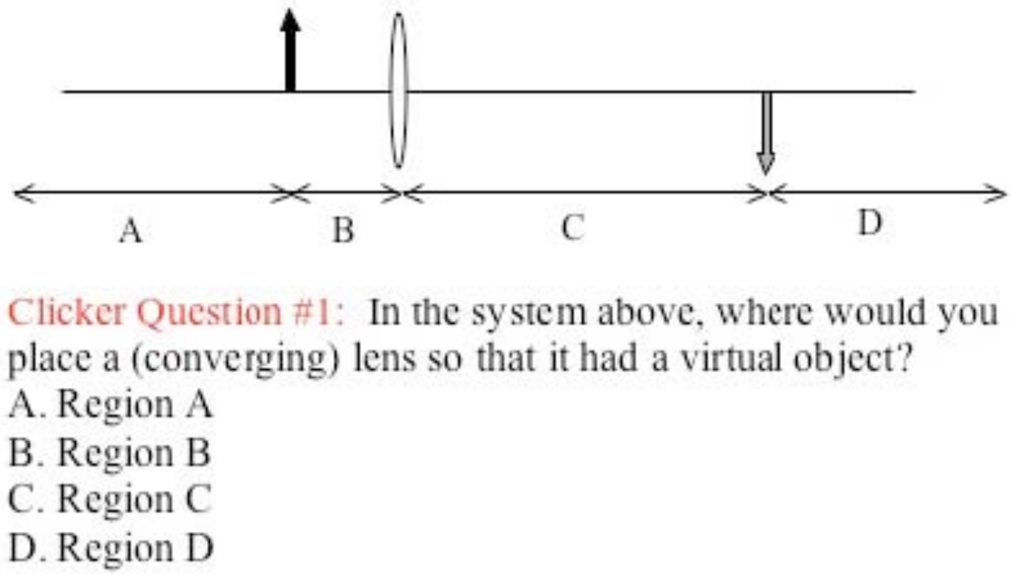

Figure 3: Example of a question used in the Peer Instruction cycle.

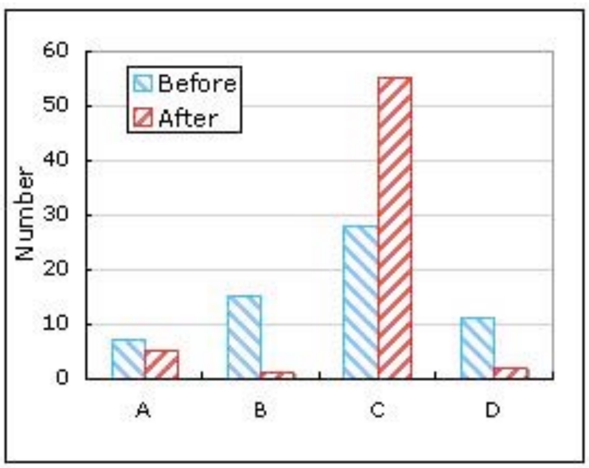

Figure 4: Student responses to the question shown in Figure 3 before (blue) and after (red) discussion.

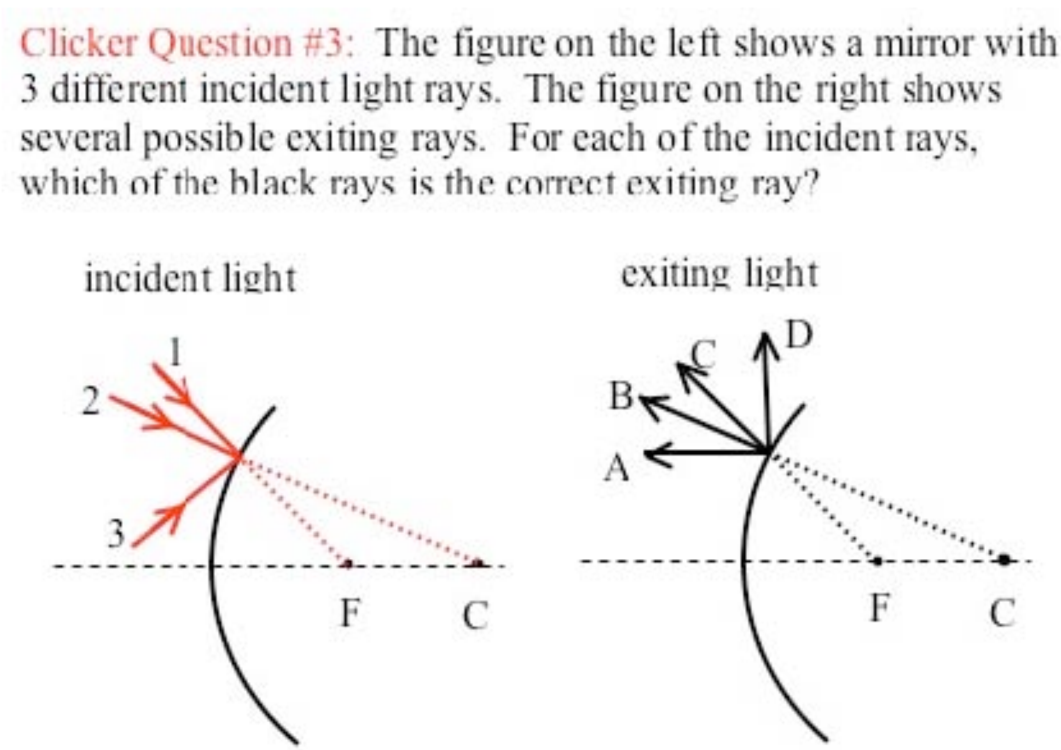

Figure 5: Another example of a question used in the Peer Instruction cycle.

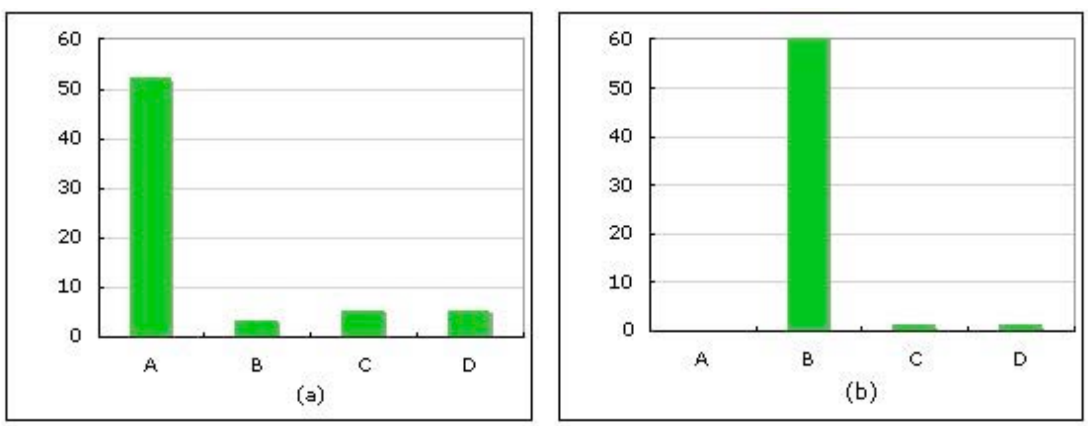

Figure 6: Student responses for (a) ray 1 and (b) ray 2in the question shown in Figure 5. Because the majority of students answered correctly, the Peer Instruction cycle was not continued for these questions.

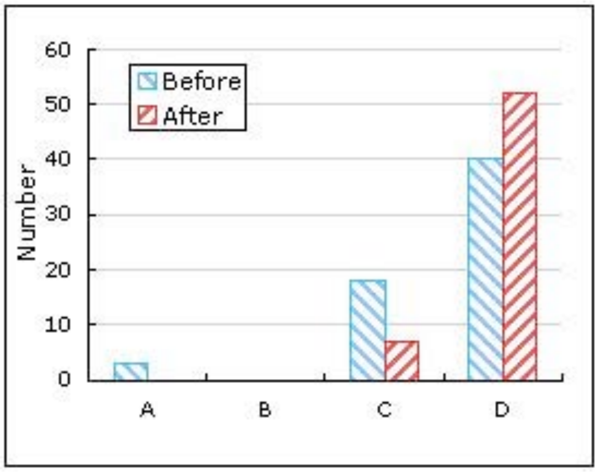

Figure 7: Student responses before (a) and after (b) discussion for ray 3 in the question shown in Figure 5.

Since the Interwrite PRS allows a variety of question types in addition to multiple choice, instructors can go beyond the standard multiple choice style question. Figure 8 and Figure 9 show two different kinds of questions that can be implemented with the multiple selection question type. Ranking questions in particular can be very powerful probes of student understanding. [10]

Clicker Question #2: A sphere lens and a cylinder lens are combined to form a spherocylinder lens. Incident light from a real point source forms two **virtual** line images, with the vertical line closer to lens. Which of following are possible combinations of the sphere and cylinder lenses? (pick all that apply.)

A. -sphere, + cyl, axis meridian vertical
B. -sphere, + cyl axis horizontal
C. -sphere, - cyl axis horizontal
D. -sphere, -cyl axis vertical
E. +sphere, -cyl axis vertical

Figure 8: An example of a multiple selection question, in which several answers can be selected.

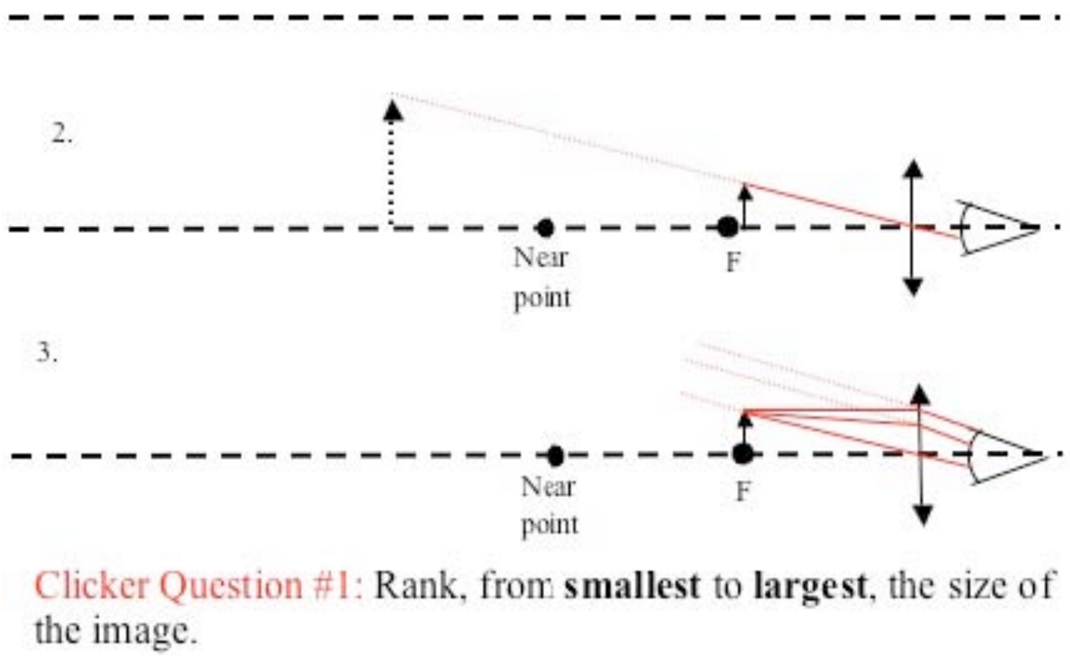

Figure 9: An example of a ranking task question.

A PRS provides a number of advantages to instructors. First, it gives students a way to actively engage with the material during class. Instead of simply sitting in their seat, listening to a lecture, they must use their understanding of the material to answer a question. Also, the students can answer anonymously, which frees them from peer pressure and allows them to answer based on their own reasoning. Secondly, a PRS provides immediate feedback to both instructor and students. As opposed to hearing answers to questions posed in class from just a small number of students, clickers enable the instructor to collect answers from the whole class. The instructor can quickly determine whether the class is "getting it," which allows the instructor to tailor the class to the students. If the students demonstrate understanding of a concept, the instructor can move on. If not, the instructor can provide additional instruction, including additional PI questions. The feedback provided to the students is also important. Students get to test their understanding and immediately find out if they are understanding the material correctly. Also, they can see how their classmates are struggling with the material. Very often students feel like they are the only ones who are struggling in a class. It can be reassuring for such students to see that other students are confused, too. Additionally, a PRS allows the questions and student responses to be archived. This can be useful for research purposes and to allow instructors to evaluate the success of individual questions used throughout a semester. The system also allows instructors to track responses from individual students, to assign grades or give credit for participation.

In conjunction with PI, we also used JiTT, a pedagogical technique pioneered by Novak and Patterson that seeks to maximize the effectiveness of class time [11]. It does this by motivating students to read the textbook before class and by helping the instructor understand what areas students find difficult. We accomplished this via Web Warm-Ups, a small number (2-4) of short-answer or multiple-choice questions that are posted on the web a day or more before a class meeting. An example is shown in Figure 10. The students are expected to read the required material and submit their answers to the questions on the web before attending the class. The questions are often designed to help the student focus on the most important or most difficult material from the reading. The instructor views the student responses before the class meets in order to tailor the class to provide help in the areas that the majority of students are struggling to understand. This makes the in-class time more efficient since the majority of time is spent where it is needed most.

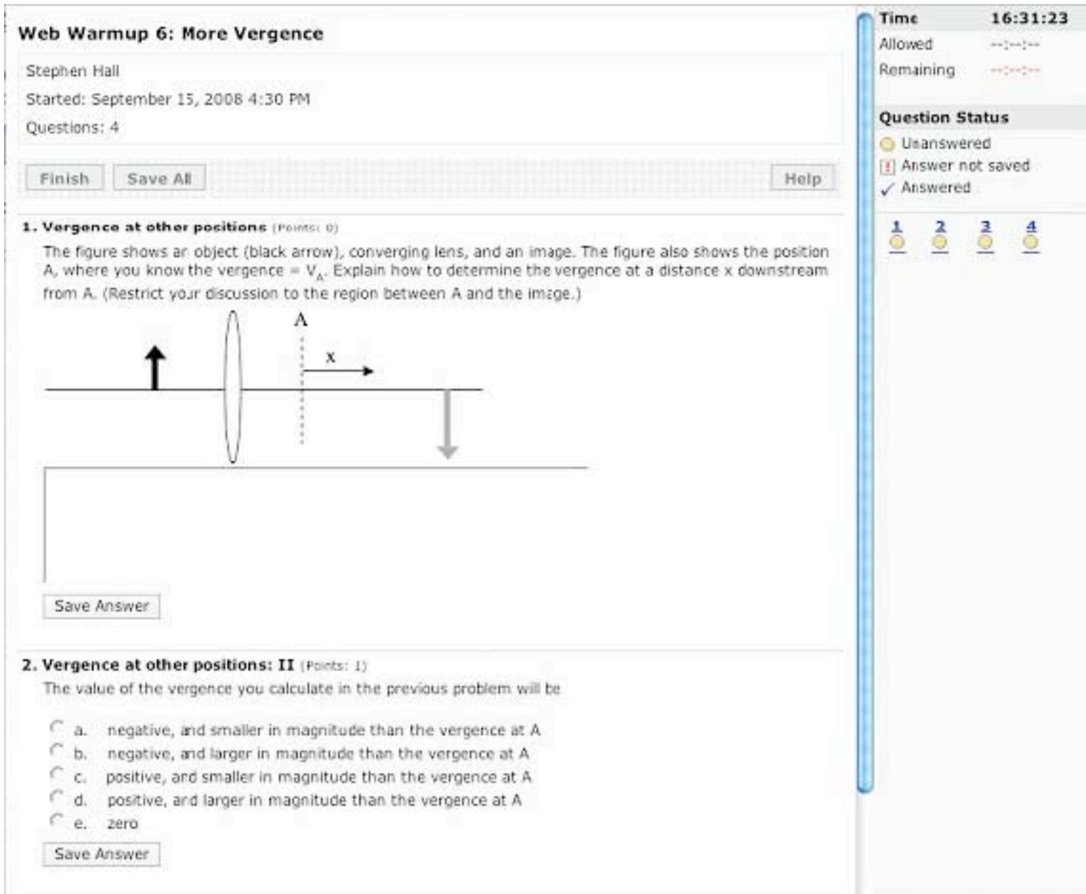

Figure 10: A screen shot of the web interface used to collect student responses to Web Warm-ups.

JiTT and PI are known to be effective IE strategies on their own. However, we have discovered that the use of Web Warm-Ups and PI together provides unexpected advantages. First, a Web Warm-Up question can serve as the first half of a PI cycle. In this case the instructor shows the student responses to the warm-up question in class and then asks students to discuss with their neighbors and answer again. As an example, Figure 11 shows a question used in this way. Figure 12 shows the student responses to this question on the Web Warm-up and after discussion in class, showing the marked increase in the number of correct responses. This use of Web Warm-Ups as part of the PI cycle frees up time in the classroom for additional material or IE activities. Second, written responses to short answer questions posed in Web Warm-Ups can be used to gain insight into student misconceptions and provide appropriate distracters for peer instruction questions. This is a valuable aid for the instructor when developing new PI questions.

Clicker Question #2: Consider an air bubble that is immersed in water. Light from a distant source is incident on the bubble as shown. Which surface of the bubble will tend to diverge the light rays?

A. the left surface
B. the right surface
C. both surfaces
D. neither surface

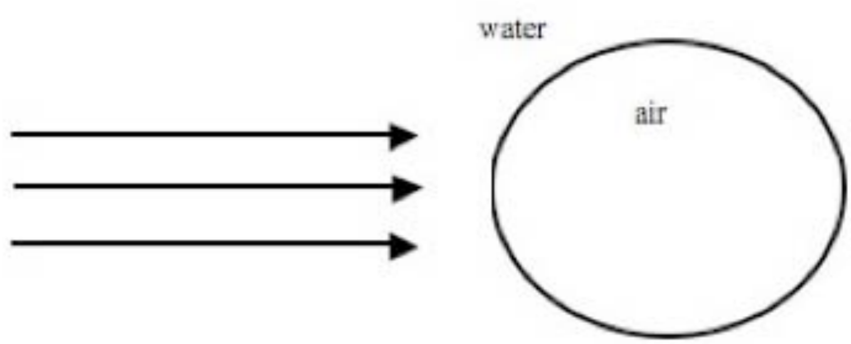

Figure 11: Example question from a Web Warm-up that was used as the first half of a PI cycle. The question was shown in class and students answered again after discussion. Student responses are shown in Figure 12.

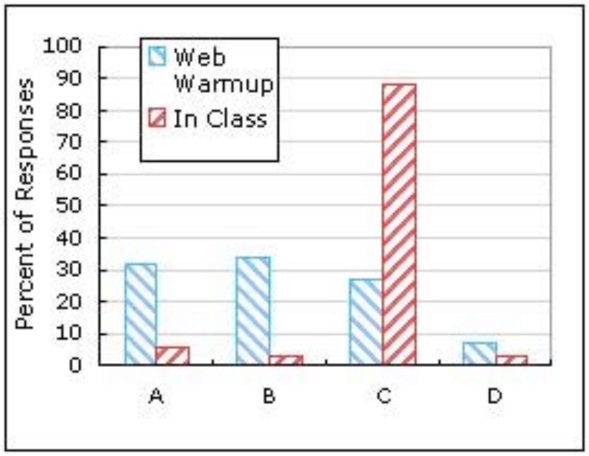

Figure 12: Student responses to the question shown in Figure 11, from the Web Warm-up (blue) and in class after discussion (red).

IV. Results

To measure whether our pedagogical changes were successful we administered a diagnostic conceptual exam as discussed in the introduction. Unfortunately, there does not exist a standard diagnostic concept exam for optics. However, we were able to obtain a draft concept exam from Sokolof who has helped design several other concept exams that are commonly used in the physics community. [12] We modified the exam slightly for our optometry student audience, and split the exam into two parts covering geometric optics and physical optics. The geometric optics exam, administered in the fall, had 36 multiple-choice questions and took about 30 minutes to complete. The physical optics exam administered in the spring had 16 multiple-choice questions and took about 20 minutes to complete. Each exam was given at the start and end of the semester. The average normalized gain in the fall was <g>=0.47 with a standard deviation of s=0.17, and in the spring it was <g>=0.5 with a standard deviation of s=0.24. These results are consistent with previous results from diagnostic concept exams for an IE class (see Figure 1, which suggests that the pedagogical techniques we adopted successfully promoted interactive engagement by the students). However, we must be cautious about our conclusion. The diagnostic concept exam we used has not undergone the rigorous validation that the other commonly used tools cited earlier have. Also, we do not have data from a traditionally taught course since we were not able to give the concept exam in our course before implementing the new pedagogical techniques. Because of this, we cannot say with certainty that our results represent an improvement over a traditional course. However, previous research has consistently shown that traditionally taught courses yield a normalized gain of about 20 percent on diagnostic conceptual exams and there is no reason to believe that the results from the optical concept exam would be very different. If we accept that our results indicate that our course is an IE one, we still cannot be certain that this is due to the pedagogical techniques we adopted. Were we already promoting interactive engagement in our class in the past? While we did have students do some group problem solving, we certainly did not systematically and thoroughly adopt IE strategies at the level described here. Despite these uncertainties we provisionally conclude that we succeeded in promoting IE in our class and that our students achieved greater conceptual understanding than they would have in a standard class.

V. Conclusion

We implemented two strategies designed to promote interactive engagement in our classroom, Peer Instruction via clickers and Just in Time Teaching via the web. Results from a diagnostic conceptual exam suggest that we succeeded in fostering an IE classroom and that our students developed greater conceptual understanding of optics than they would have under standard lecture-based instruction. In addition, we experienced a subjective improvement in our class. Students appeared to enjoy using the clickers and seemed to be truly engaging with the material when answering the clicker questions. Many students commented that they enjoyed the style of learning and found it helpful.

An important observation from our work is that clickers alone do not make an IE class. The framework of Peer Instruction is what promotes intellectual engagement of the students, which in turn is responsible for improvements in conceptual understanding. The clickers are an efficient tool for implementing PI, but are not themselves responsible for improved student performance. One could explore other technologies for gathering student responses. In fact, our original proposal was to have the students use their laptops to submit their responses, but we could not find free software to do this well. Interwrite does sell a software version of their clicker, but since a sufficient number of hardware clickers were available to us we decided to use them.

In the future, we hope to have the diagnostic exam administered at other colleges of Optometry in order to build up a more extensive database of results for a variety of teaching techniques to verify the trend that we have observed. We hope that the improved student learning we have observed using IE techniques will encourage other instructors to adopt such techniques in their classrooms.

Endnotes

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[12] R. K. Thornton and D. R. Sokoloff, "Assessing Student Learning of Newton's Laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula," Am. J. Phys. 66, 338-352 (1998); see http://www.physics.umd.edu/perg/tools/diags.htm for an overview of the diagnostic exams available.