Transitioning from lecture to group problem-solving: Michael Murray

Project Summary

An introductory physics professor aimed to increase student learning by redirecting class time from lecturing to group problem-solving activities. Performance on homework and exams was compared between students who participated in group problem-solving and students who participated in a lecture-based class setting.

I. Background

The introductory calculus-based physics sequence is designed to introduce scientists and engineers to the basics elements of classical physics: Newtonian mechanics and gravity, thermodynamics, waves, electricity and magnetism. Physics classes are traditionally taught in lecture-only format. I incorporated group problem-solving worksheets into daily classes in order to

- push students to describe and illustrate difficult concepts
- maximize peer interaction
- improve performance on exams

I. Implementation

I applied a form of Mazur's (1997) peer instruction techniques by having students complete worksheets in groups during class time. In contrast to traditional algebraic formulation of physics problems, my worksheets contained elements that required students to explain physics concepts using words and pictures. We discussed worksheet solutions in class; students would come to the front of the class and explain their answers to their peers. Later, a TA later graded the worksheets using solutions I developed.

I. Student Performance

Students in the class that used worksheets to guide interactions obtained final course scores 4.5% higher than those in the traditional lecture course. This difference reflects the fact that students in the worksheet-based class scored significantly better on three of the four exams. Several students in my class commented that they enjoyed the group problem-solving and when formally surveyed mid-semester, most students reported that the worksheets helped them better understand the material.

I. Reflections

One advantage of combining lecture and group activities in each class was the change of pace it offered. I also enjoyed the increased opportunities for me to talk with individual students during class time. As the students became more comfortable with the process, they were more willing to come to the front of the class and explain their solutions. This would often lead to lively discussions and, in general, made the class environment more social. Witnessing students grapple with difficult concepts helped me gauge student understanding; this, in turn, allowed me to address common misconceptions during lecture. The benefits of peer-interaction and the learning gains from having students illustrate and describe difficult concepts outweighed the costs of lost lecture time; I plan to continue to use worksheets during my introductory physics course.

IN-DEPTH DESCRIPTIONS

Background

Calculus-based physics II (PHSX 212) is the second semester of a two-part calculus-based introductory course. The class is comprised mostly of engineering, architecture, and ROTC students, and is typically a required course for all students enrolled. Physics II concludes the study of classical physics initiated in Physics I and is the precursor to quantum mechanics and relativity.

The course is centered on several content goals including:

1. Extending concepts of energy and momentum to waves and electromagnetic fields
2. Exploring concepts of electric charge and electric current
3. Developing the link between electricity and magnetism
4. Synthesizing a description of light as electromagnetic wave

The concept of energy is vital to physics and is essential for engineers to understand and apply in their work. Therefore, this course also aims to train students to "think like physicists" by refining problem-solving skills, using symmetry to simplify situations, and having students verbally express difficult concepts.

I considered augmenting my lectures with other teaching techniques because I repeatedly encountered challenges getting students to understand notoriously difficult concepts such as

- the relationship between potential and field
- conservation of current
- the relationship between electric potential and energy.

Getting students to understand these concepts is crucial if I want to meet the content goals for the course. Compared to the first semester of Physics, it is difficult to find real world examples of the concepts discussed in Physics II. Therefore, students relate less to the material. Moreover, students equipped with mathematical skills tend to look for ways to apply formulas to physics problems without examining the problems closely. While I often observe that students can solve physics problems using calculus, I have doubted whether students truly understood the phenomena they were calculating. For these kinds of problems, "thinking like a physicist" involves 1) simplifying a problem 2) identifying where the energy is in the system, and 3) only then potentially using equations to solve a problem.

In fall 2006, I altered my teaching approach by incorporating group problem-solving worksheets into what was formerly a lecture-based class period. I chose this particular approach based on student feedback during first semester physics. In that course, discussion sections appeared to help students grasp and articulate the material above and beyond the coverage provided by the lecture itself. Physics II does not offer these discussions, so I decided to incorporate more discussion during class time using these worksheets. Furthermore, there is empirical evidence to support the use of peer instruction in classrooms for enhancing conceptual—as compared to mathematical—problem-solving (Mazur, 1997). I wanted to extend Mazur's peer instruction methods by using in-depth worksheets (as opposed to single verbal questions followed by a Concep Test) and asking students to illustrate their understanding in pictures, as well as words.

Specifically, I designed these worksheets to meet the following goals:
1) I wanted to push students to describe difficult concepts in words, not math. 2) I wanted to minimize my own talking in class and maximize student interaction to keep students engaged and let them learn from one another.
3) I wanted to know if a deeper conceptual understanding through the worksheets and peer interaction would translate to better student performance on exams.

Implementation

Through group work on open-ended worksheet questions, I challenged students to put difficult physical and mathematical concepts into words.

During most classes, I dedicated time in the middle of class for students to complete worksheets. These worksheets were based mostly on analyzing illustrations. I also asked students to articulate the illustrated concepts verbally, as opposed to using equations. I encouraged students to work in groups and I walked around the class, listening to discussion and helping when needed. After students completed the problems, I randomly selected a student to draw their answer on a blank overhead at the front of the class. They would then be asked to explain their thought process to their peers. Alternatively, I had them explain their answers to fellow peers in smaller groups. Regardless, we discussed the problems as a class, reinforcing correct answers and correcting wrong ones. This whole process typically took about 15 minutes, after which I resumed lecture.

Students handed in the worksheets at the end of class; the worksheets were graded by a TA and returned to students. Participation comprised half of the worksheet grade and at the end of the semester, the worksheets comprised 6% of the final grade.

Observations of student performance

Student learning was measured by worksheets and exams. During the semester I pioneered my worksheets, the same course was taught concurrently in a traditional lecture style by a colleague. We assigned the same homework and tested students using the same exams. The exams were comprised of half multiple choice questions and half short-answer/picture questions similar to worksheet questions. Mean exam scores for students in the worksheet-based class were significantly higher for three of the four exams (Figure 1 below). The mean final course grades for students who used worksheets during class were 4.5% higher than the traditional lecture course (Figure 2 below). While the entire distribution shifted toward higher grades when worksheets were incorporated into class, a particularly notable improvement was in the modal scores. The most common grade for the lecture-based course was between 65-70% compared to the course involving worksheets, in which the highest number of students achieved 75-80%. This shift is consistent with the results Eric Mazur achieved he enhanced his physics course with peer instruction techniques (Mazur, 1997).

I also surveyed my students midway through the semester to gauge their perception of the value of worksheets. Most of the students agreed or strongly agreed that the worksheets helped them learn the material better.

Anecdotally, these worksheets appeared to help students better understand difficult physics concepts. Students seemed more willing to work with peers as time passed, and performance on worksheets improved over the course of the semester.

When students made mistakes expressing concepts in words, their misconceptions were similar to those discussed in the "*Instructors Guide*" to the textbook *"Physics for Scientists and Engineers."* One direct benefit that came from discussing worksheets is that I could use students' own words –as opposed to the text -- as a starting point for discussing these misconceptions. For example, one common conceptual stumbling block for students in physics involves understanding that if a variable equals zero, the rate of change of that variable is not necessarily zero. Distinguishing between zero electrical potential and zero electrical field requires that students understand that the field is the derivative of potential energy. Even after completing homework problems, students could not explain this concept in words when they attempted the worksheets. Because the completed worksheets provided examples of the misconceptions, I used the mistakes I identified in the worksheet solutions as a springboard for providing correct explanations and new examples of electrical potential and field. Such timely responses to misconceptions may be one reason exam scores improved with the use of worksheets in class.

Reflections:

The main benefit these worksheets provided me as a teacher was that they allowed me to better assess gaps in student knowledge. Using mathematics-based exams makes it difficult to identify what students don't understand. At the same time, just because a student can use the correct equation doesn't mean (s)he understands the concept.

However, when students presented and discussed their answers in front of the class, I was able to hear their misconceptions. I could also listen as students discussed the problems among themselves to better understand their thought processes; this way, I could identify the *reasons* they didn't arrive at the right answer. Consequently, I found that one major value to the worksheets was that they generated and prioritized topics for class discussion. During these discussions I was able to provide students with immediate feedback.

Having students work in groups to complete the worksheets influenced the classroom environment in ways other than purely academic. I got a chance to talk to the students and learn their names. By the end of the semester the students were much more social amongst themselves and willing to work in groups to solve the problems on the worksheets than in lecture courses I had taught previously. Still, some students did not want to work in groups and continued to attempt the worksheets on their own. Therefore, this year (2007) I have arranged to give only one worksheet to every group of three students to further encourage collaboration.

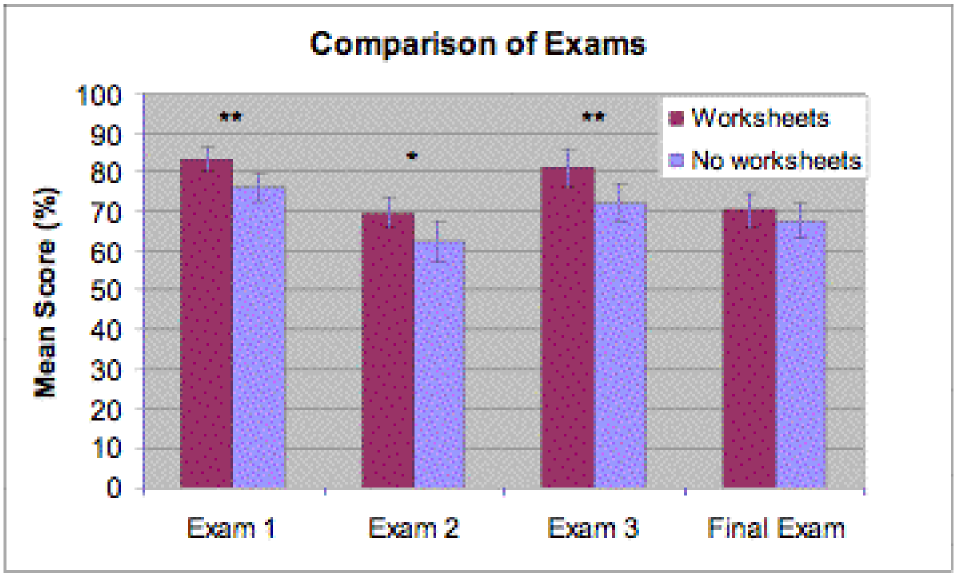
Incorporating group work into my lectures has made me realize the importance of the physical classroom arrangement. I teach in two different classrooms. In one room chairs are fixed in rows, making it difficult for students to interact with peers. The other classroom is more versatile; students can move their chairs to face one another and consequently, their interactions are less-strained. In the future, I will request rooms that are furnished in ways that facilitate student interactions.

I am also trying to improve the degree to which these worksheets inform my teaching plans for the next lecture. In Fall 2006, I had a TA grade the worksheets and as a result, I did not know what percentage of the class achieved the correct answers. This semester I have asked the TA to summarize student responses after each class. This way, the worksheets can better influence the topic or rate of my next lecture. I am also going to post solutions to the worksheets on Blackboard.   I will use student solutions, sometimes with my own comments. I believe that providing examples of poor and excellent solutions will be instructive for students aiming to improve their performance on the worksheets.

References

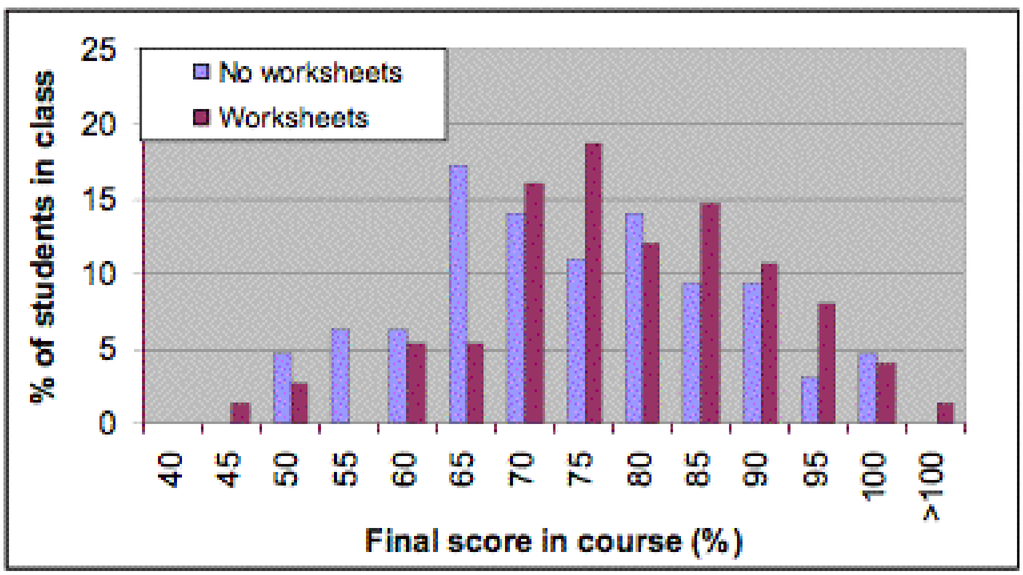
Mazure, E. *Peer Instruction.* Prentice Hall, Inc. Upper Saddle River, New Jersey; 1997.

Figure 1.



Comparison of mean exam scores for students in physics classes with and without worksheets. Error bars are ± 2SE. Significant difference in mean scores (*p*<0.01) indicated by ** (two-tailed t-tests, df = 131). Significant difference in mean scores (*p* <0.05) indicated by *.

Figure 2.



Comparison of the grade distribution in physics classes with and without worksheet supplements.