TEACHING INNOVATIONS IN AN INTRODUCTORY PHYSICS COURSE FOR NON-SCIENCE MAJORS

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I have made several innovations to *Physics 114: Physics of Sound*, a course for Communication Disorders and General Education students at the University of Massachusetts. These changes include the use of a network of wireless communication devices called a Personal Response System, on-line tutorials and classnotes, a collaborative discussion section, exam corrections, microthemes, extra-credit papers, group extra-credit projects, and the use of student teaching assistants.

Introduction

Several innovations, including the use of a "Personal Response System" (PRS), and the use of student teaching assistants, were integrated into *Physics 114: Physics of Sound*, a course presented to non-science students, in recent years. Below I give details of these changes and some student reactions to them. The course satisfies a University of Massachusetts General Education requirement and is an introduction to acoustics, with special emphasis on the speech and hearing mechanisms. It is required of sophomore majors in Communication Disorders (ComDis), but open to students in all majors. About 15% of the students are majors in other departments.

The students in the course are non-science majors and often enter the course with considerable trepidation. Thus, the course is designed for individuals who are not strong in mathematics; it is based primarily on a pictorial and graphical approach, with some algebra, of course, that students are capable of handling. Interestingly, because of the makeup of the Communications Disorders Department, 90% of the students in the course are female. This high percentage of female students in a physics class in a coed university is very unusual. Enrollment varies from 60 to 90 per offering.

I developed *Physics 114* in 1974 because of my own interest in sound, and because my wife, who is a speech and language pathologist, suggested that Communication Disorders majors might find it useful. Soon after, the Communication Disorders department made the course required of all its majors as a prerequisite for their Speech and Hearing Science courses. That department may be unique among similar departments at universities with this major in having

this requirement. The policy of our Physics Department is for an instructor to teach a course three or four times and then to move on to another course. In three separate assignment periods, I have taught the course eleven times in the 26 year span of its existence. I have taught the course four times since 1997.

Innovations were made in the course as a result of advice from other instructors, to follow my own ideas on what could be useful, and as a result of being a part of the Science, Technology, Engineering, and Mathematics Teacher Education Collaborative (STEMTEC) Program at the University of Massachusetts Amherst.

The course is designed to be student-active, that is, the main feature of class time is students working, generally in small groups, to discover for themselves the answers to provocative questions and problems presented during class. This process is facilitated by a Personal Response System (PRS), a classroom communication device that allows students to send answers to a central computer where they can be recorded and summarized for the class. Some lecturing is done, but students are expected to have read the material to be treated in any particular class before that class. A set of classnotes [1] and a website are provided for that purpose. An important feature of the class is the illustration of important points by means of physical demonstrations; in a course on sound it is important to hear what you are talking about. However, this feature is not an innovation in a physics course and will not be discussed further here.

Among the more notable features to be discussed below are PRS, an on-line tutorial, the use of undergraduate student teaching assistants, and group projects. The main goal of these and the other activities discussed is to provide many pathways for students to learn with an emphasis on a constructivist teaching philosophy, in which the instructor is only a facilitator of the learning carried on by the student herself.

Techniques Used

Some of the innovations used are described in this section.

Personal Response System:

The Personal Response System, developed by Better Education, Inc., of Yorktown, Virginia, is a wireless communication device that we installed to replace the wired networked system *Classtalk* (also developed by Better Education, Inc.) which had been used by my most

recent immediate predecessor in the course, Prof. José Mestre [2]. Both systems allow student communication with a central computer that compiles and displays student answers to in-class questions. While *Classtalk* is an excellent system, I find PRS is much simpler to use and has a less steep learning curve for the students. Our *Classtalk* system had been breaking down regularly due to old age. *Classtalk* is much more flexible, allowing various answering procedures, and gives the instructor more comprehensive information; PRS allows only answers 1-9. Nevertheless, I found that was sufficient and preferable for my purposes.

With PRS, each student uses a small handheld infrared transmitter much like a TV remote control. A receiver, mounted on the front wall of the classroom to detect the student responses, is connected to a central computer that contains proprietary software to tabulate and record the incoming data. The final results are projected as a histogram on a screen in the front of the class. Data is recorded in a text file that is easily transferred to a spreadsheet program. While it might be possible to have students purchase the transmitters (approximately $50 each), the Physics Department purchased a large set of these for use in several classes. At the beginning of each semester, each student was assigned a particular transmitter number, and at each class the student checks out that particular device. An answer transmitted from a device is identified as coming from that particular device. Thus, for example, attendance can be taken with the system and quizzes can be given. By placing groups of three transmitters in plastic bags, one student could pick up the devices for herself and two classmates from a rack near the door. Even with seventy students there was no class delay in setting up.

With either system, students work actively on questions or problems, discuss these in small groups, present individual answers, discuss as a class, and see how they did via a projected histogram. The main advantage is student participation, but seeing how they are doing relative to the rest of the class is no small benefit. The instructor has immediate access to student feedback as well, and can tailor his or her presentation to how well the students are doing on particular tasks. I also use PRS to take attendance, which earns credit on the final grade. Here is a typical in-class question:

The use of the term "sound wave" in air is meant to describe:

1) the position of air molecules
2) the velocity of air molecules
3) pressure variations in air
4) the flow of energy through air

The entire set of questions can be seen on-line at the course website discussed in the next section. As one can see, not all questions are mathematically couched. They tend to be qualitative, and sometimes even ambiguous, so that student discussion is provoked. Most of the questions I have used were developed for *Classtalk* use by Prof. José Mestre for the student-active approach he has used for many years [2,3]. Once the students have keyed in their answers, I ask for a student to explain her answer to the class. In the ideal case, there is disagreement among the students so that a lively discussion ensues. However, I have always found it difficult to get students who are unsure of their answers to volunteer to take part in the discussion. Thus, a student orally responding to the question is usually one who really knows the right answer and debate is sometimes limited. Nevertheless, students are very appreciative of the approach, because they are getting a chance to test their understanding with the material presented in this way at a pace that allows them to keep up.

A crucial aspect of such an approach is the decrease of lecture time available to present material in a standard manner. The students are encouraged to read the classnotes before class time. Some actually do this! It is not a great burden since, on average, we cover only five pages of notes per class period. Short lecture and demonstration periods are interspersed with the questions in the class period.

On-Line Tutorial and Classnotes:

The course has a website at http://www-unix.oit.umass.edu/~phys114/. On the site are classnotes [1] written by colleagues and me. While the students have a printed copy of the classnotes, made available through the University bookstore, the on-line version contains animations of waves, etc. that are impossible to reproduce adequately in the printed version. The other useful feature is a tutorial containing all the PRS questions used in class. A student not following the class discussion, missing class, studying for an exam, etc., can actively work on a question on-line. She chooses a multiple-choice answer, is told whether it is correct or not, is offered a reference to the classnotes and a helpful hint, and then, if necessary, is given a detailed correct answer. In the latest offering of the course, students were also able to obtain a CD-Rom disk containing the website if they liked. Despite giving out many of these, the on-line site received about 300 hits during the semester.

Collaborative Discussion Section:

An afternoon discussion section is required to fit into the students' schedules. This feature was instituted some years ago by Prof. Mestre to help replace some of the help sessions

necessary in this course. From the very beginning 26 years ago, it was evident that the lectures I was presenting were not enough for the all the students to master the homework and other material of the course. Thus, I instituted help sessions at various times during the week. Offering a scheduled discussion session is a much better way to fit in such a session. It is optional and about half the class attends. I use it in a group collaborative approach, where groups of students help each other on the weekly homework, while the course TA's and I go from group to group offering advice. This procedure is much preferable to one in which an instructor is standing at the board doing the problems for the students as is often typical in discussion sessions in other courses.

Microthemes:

Because of the large class size (71 in Spring 2000) computer graded homework and exams are very timesaving. However, I prefer at least some essay questions on exams. Thus, the hour exams usually each have one microtheme question included. A microtheme [4,5] is an essay that has a short length requirement. In my case I present a box, 7.5in x 3in, into which the answer must fit. The question is always qualitative and an accurate answer requires the student to understand the meaning behind the math, rather than having, for example, memorized a formula. An innovation is that I give out three possible questions during the week before the exam, so the students can prepare answers *ahead of time*. (This forewarning unfortunately does not result in 100% correct answers; indeed, in Exam 1 in Spring 2000, only 25% of the class got full credit for the essay, while, in Exam 2, that number improved to 63%.) The questions are easy to grade; one spends perhaps 2-3 minutes per student. The major advantages of the questions are that they force the students to think deeply about the three selected topics before the exam, and they are an excellent diagnostic tool for determining qualitative understanding. A typical question is,
"Why does a standing wave 'stand' rather than 'travel'?" This question requires that the student understand the distinction between standing and traveling waves, and understand the role of reflection at boundaries and interference in the establishment of standing waves. It is easy to tell from the answer in the box whether the student has mastered each of these rather complex ideas in at least a qualitative way.

Exam Corrections:

The idea of a "pyramid" exam or its variation, as a help to learning, is very popular among STEMTEC participants. Locally, this process is often formulated so that after finishing and handing in an individual answer sheet, students rework the exam in small groups, getting 10% or more of their grade for the group answers. I prefer a variant of this. After an hour exam, I

announce that students may gain 5% of their test grade (sometimes less) by writing a couple of sentences for each wrong answer, explaining why it was wrong, and what the correct answer is and *why*. They have a week to produce these corrections and are allowed to consult any source. This optional assignment can result in as much as three pages of corrections, which are time-consuming to assess, but invaluable in getting students to think about their mistakes. It also puts a premium on understanding not only what the answer is, but why. Students report this exercise is extremely useful. I explained the usual pyramid exam procedure to my TA's (former students in the course) and asked them whether they thought they would have preferred that or my approach. They were unanimous in favoring my approach.

Extra Credit Options:

Since the Communication Disorders students are very interested in performing well in this required course (most need to get into graduate school to obtain a master's degree for certification) earning extra credit is a popular recourse. There are two main modes of receiving extra-credit points: essays and projects. At two points in the semester, a student may gain extra credit by writing a five-page paper. I like the idea because most of the assignments in the course are multiple-choice and this gives the students a chance to show their extended writing abilities. Topics for writing have varied widely; examples are earthquakes, the physics of singing, echolocation in bats, etc. The two papers, if they gained full credit, could raise a student's grade by 6%, or one letter level.

In accordance with suggestions from writing specialists, papers go through a drafting process. A first draft is handed in; I distribute it to another student writer, who prepares a detailed evaluation of the paper using a form I designed. The paper is then re-written on the basis of the suggestions from the peer review. In an ideal world, I would read the draft as well and give the writer feedback, but I have not done this every time. I see the first draft and the peer review when I read the final draft. The entire process is done in plenty of time before the end of the semester so that the student is certain to see my comments on her writing (unlike many "term" papers that never actually get picked up by the student).

A second extra-credit possibility is a group project. Groups of students, preferably four, but occasionally two, three, or five, decide on a project that they can present as a 15-minute oral demonstration on some class-related subject. The subjects vary from a spectral analysis of a musical instrument to the physics of the middle ear. I observe the demonstration and give a group grade. Each student is then required to summarize the project in an independently written, four to

five page paper, which results in an overall project grade for that student. The maximum extra credit is an 8% grade change. In principle, the best demonstrations would be presented to the whole class if there were time, but I have not been able to fit it in. Students review drafts of each other's papers, which helps improve the final product, before I read them.

An advantage of this process is that students are working together and are teaching each other. The papers are less stilted and less formal than those described above because the projects go beyond the usual textbook formulation and involve some original thinking. The students find these projects fun to do and often become very enthusiastic about the ideas they develop. The oral presentations that they must make help develop yet another useful skill.

Topics here can be quite unusual. One group in 1999 decided that they wanted to break a wine glass with sound waves as seen in a popular television ad for recording tape. This is not easy and requires a special speaker, which I did not realize at the time. But what the students came up with was interesting: they could not break the glass (actually a beaker), but they could see its resonance by noticing the motion of sand sprinkled on a card placed on top of the beaker. The approach wasn't as dramatic as breaking the beaker, but it was probably more educational. (In Spring 2000, I found the department had the required speaker and amplifier and I incorporated the breaking beaker as a *pièce de résistance* classroom demonstration.)

The extra-credit paper avenue has not been as popular in recent times (in Spring 2000, only three students used this option) as the group project. This spring, 36 students involved in ten groups participated in the latter approach to extra credit. Part of the reason is perhaps that the project is worth more credit, but I decided that the group work was a more valuable experience and raised the possible point total to encourage its use.

Student Teaching Assistants:

Having student teaching assistants is probably the single most useful innovation in the course. I ask three of the top students from the previous year's class to act as TA's in the current semester. The TA's are "paid" with independent study course credits, up to three, depending on how much time they are willing to spend. Amazingly, the students I ask have always agreed, and this semester I had two wonderful students return for a second year's work. Often good students come in to *volunteer* to become TA's in the course. The TA's do not do any grub work such as grading homework, doing errands, helping with proctoring, etc; they only tutor, hold office hours, and teach help sessions. This feature provides many extra hours a week of help for students in the

course, who seem more willing to look to their peers for help than to come "bothering" me, even though I do encourage them to come to me for help. One of the goals of the STEMTEC grant was to encourage students to enter science teaching. It is possible that this student teaching experience may encourage former Communication Disorders TA's to go into school special education rather than into the more lucrative hospital work. While special education is not explicitly science teaching, it can affect the quality of the latter rather directly. The independent study grade is based on my assessment of how well the TA performs in that role, including mundane things like adequate preparation for duties and not missing office hours, and more importantly how well she interacts with the students as I observe in the discussion section. In some cases, I have in addition required a paper on some aspect of sound beyond that covered in the course.

Conclusion

I have made no formal effort to determine whether the students learn more or retain the information longer with the use of these innovations. I do know that my student evaluations have risen greatly over the last few years, as evidence that the students very much appreciate the way I now teach. My experience is that happy students are much more likely to learn, so I recommend these approaches. ■

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