Electronic Student Response Found Feasible in Large Science Lecture Hall

Inexpensive, Homemade System Sparks Student Attention and Participation

Joel A. Shapiro

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In recent years, science educators have been directing more of their attention to the surprising ineffectiveness of the traditional lecture in teaching introductory college-level physics (Wilson, 1994; Laws, 1990, 1991; and Milton, 1972).

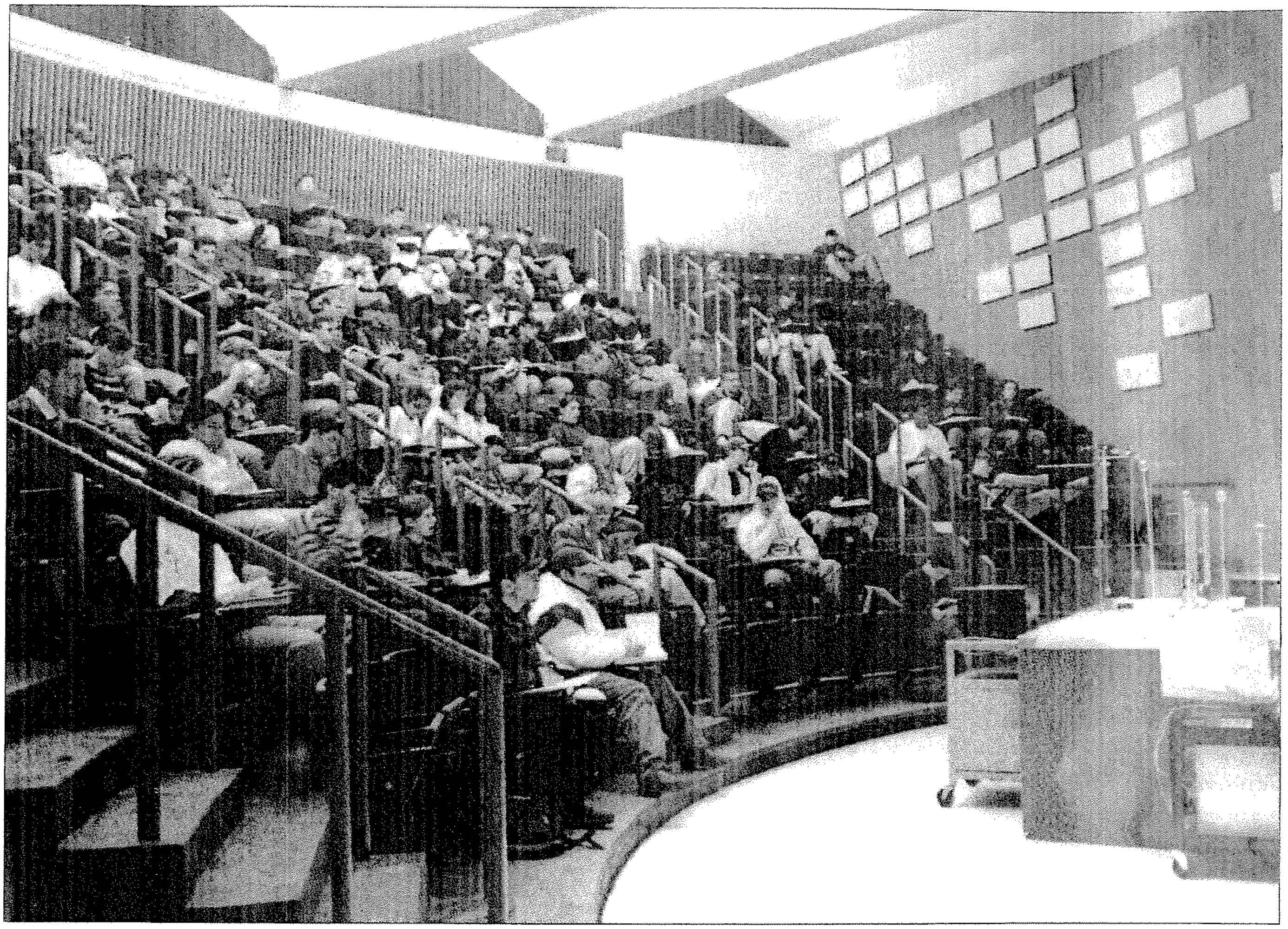
Their research supports the argument that smaller, more interactive frameworks teach better than the conventional lecture. However, with colleges and universities enrolling thousands of students every semester in introductory science courses, these institutions are unlikely, for financial reasons, to give up the large lecture format anytime soon. Thus, as emphasized by Ehrlich (1995), it is vital that ways be found to make large lecture classes more efficient.

One of the principal ways to make the lecture more effective is to make the student's experience less passive, *e.g.*, requesting active participation through responses. Unfortunately, encouraging verbal responses or the raising of hands have proven unworkable in a large classroom setting. Instead, Littauer's (1972) experience has shown students to be much more willing to participate using electronic responses. With the vast improvements in digital technology, it is now feasible to interact with a large number of students by means of an electronic student response system.

A lecture hall response format also provides a means for the instructor to focus on conceptual questions, which tend to get inadequate attention from the student. The kinds of questions asked on Hestenes' conceptual diagnostic tests (Hestenes et al 1985, 1992a, 1992b), for example, are not generally asked on homework assignments or exams. Neglecting these questions leads students to assume that basic conceptual understanding is less important than the ability to work out a numerical problem, which more often appears in such contexts.

Conceptual multiple-choice questions, however, are ideal for use with a student response system, and their appearance will help convince students that conceptual *and* procedural comprehension is necessary. In addition, a histogram of responses will immediately notify the instructor if a number of students are having trouble. By recognizing problems, the instructor can address those blocks preventing students from grasping the material. If we are unable to identify fundamental misconceptions, much of our instruc-

Joel A. Shapiro is a professor in the department of physics and astronomy, Serin Physics Laboratory, Rutgers University, Piscataway NJ 08854; e-mail: shapiro@physics.rutgers.edu.



A response system for a large lecture hall, like this one at Rutgers University, can be used to take attendance, give quizzes, and assign other means of awarding grades.

tion time is wasted (Mestre and Touger, 1989). When the histogram is projected so that the students also see the results, the realization that others disagree with them can spark discussion; this in turn motivates the instructor to explain *why* wrong answers are incorrect.

Several commercial student response systems are currently available, but they are quite expensive if installed on a large scale—in my department at Rutgers, most of our large lectures are given in a hall with 330 seats. We asked for quotes on a system that allowed individual responses from each student. Classtalk declined to quote on a one station per student system, citing the advantages of collaborative learning. Instead, they quoted a system with responders for every third seat at $64,000. Such a system would not permit the varied methodology we hoped to develop, which would not preclude collaboration but should not depend on it in all circumstances. A different, complete system, with one station per seat, was quoted for Rutgers Facilities at about $150,000. Other commercial systems from IBM and RSI were roughly the same price (see references).

This amount of money may be available to departments constructing new lecture halls or to those with National Science Foundation or FIPSE grants, but such funding was not available to us. I suspect many science departments are in the same predicament.

Small amounts of money in teaching innovation grants are often available from universities, and a reasonable level of technical expertise can also be found in a large science department, making a homemade system a possibility. Of course, the full cost of a homemade system requires considerable contributions of faculty and staff time. Such a system was built over 20 years ago by Prof. Littauer (1972) at Cornell University. His homemade system, chosen because of financial constraints, produced excellent pedagogic results. In 1993, Suzanne Brahmia suggested, based on her favorable experience with the Littauer system, that our department build such a system. While the design and capabilities of the system we built are quite different from his, the spirit and circumstances behind its creation are quite similar.

Rutgers has a Teaching Excellence Center that awards grants of up to $5,000 to promote educational development. Prof. Horton of our department had an NSF grant (DUE 92-54247) that could match such funds, so I began with $9,000 and a mandate to complete as much as I could of the system. This was not quite enough to do the whole lecture hall, but in the fall of 1994 an additional $4,500 was allocated from departmental funds. In addition, some $1,500 of mechanical shop time, $2,000 of student labor, and $150 of an electrical engineer's time should not be overlooked. In the end, the system was built for about $17,000. This amount includes a fairly large number of spare parts needed to maintain the system ourselves. A maintenance contract on a commercial system would be very expensive, but we will be able to maintain ours without additional funding. Thus, we have proven it is possible to implement a large student response system with minimal funding.

One of the aims of this article is to share my experience with the wider teaching community. For those willing to consider taking on the task of installing such a system, I hope that this account will enable you to do so with somewhat less money and far less effort.

GOALS OF THE SYSTEM

The installation of a student response system was motivated by the desire to elicit increased attention and curiosity from students. Interest from students is sparked when their responses to thoughtful questions are asked and heard. For this, a system does not need to distinguish who responded to a question. In our first application we produced only a histogram of responses to a multiple choice question. This *anonymous* mode is different from a *tagged* mode, where each response identifies the particular seat from which it came (and thus, the student who sent it).

Opinions differ on the advantages and disadvantages of tagging. Therefore, I wanted a system that could be used in either mode. A dual purpose system would enable faculty with conflicting views on the effectiveness of a response system to experiment using the two settings. The advocates of the anonymous mode feel that it induces a warm, nonjudgmental atmosphere that encourages learning. On the other hand, a system able to record the identification number and answers of each student could be used to take attendance, give quizzes, and to allow other means of awarding credit. The latter, pragmatic approach has many advocates because faculty realize that the majority of students are primarily motivated by grades. It should also be noted that a tagged system enables the teaching staff to give individual attention to students and to follow the progress of certain students, even if the data is not used for grading.

DESIGN OF THE SYSTEM

What does one need, at a minimum, to build a system that will accomplish these goals? With limited funding for such a large number of seats, it was essential to design a system with a minimal cost per station. Each student station not only had to be inexpensive, but also impervious to damage or removal, and had to fit into an existing seat structure. For input, a few buttons, perhaps five, were enough to handle most multiple-choice questions. All 10 digits were necessary, however, to enter standard student identification numbers. A minimal level of feedback was also necessary to assure the students that their responses were being heard.

We started with a somewhat jaundiced view of how students would treat the stations, so we rejected membrane keypads and anything held in place by a mere wire. We settled on a system that uses surplus telephone keypads for student input and three LED lights, red, yellow, and green, which can be used in diverse ways to forward minimal feedback to the student. With a small printed circuit board, the station itself cost about $7.50. In order to install these in a secure manner, we replaced each armrest with one machined in our mechanical shop. After the stations were in service for a month, we learned that the LEDs needed the protection of a hard transparent plastic shield, which was also made in our machine shop. The cost of these armrests and shields, per seat, was about $4.00 for materials and a comparable amount in shop time.

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The most difficult design issue was how to unite so many inputs. Wiring an already existing hall is extremely time consuming. The possibilities of infrared communication were tempting because they avoid wiring, but I was told that 330 seats in a room was more than such a system could handle. Having some feedback capability necessitated inserting transmitters and receivers on each station, making it too expensive and perhaps too vulnerable.

So I used a telephone keypad and three LED lights connected by an RJ45 socket for simple wiring using modular cable.

Clearly one cannot bring 330 cables together and plug them into a standard computer interface. Our lecture hall is shaped like an amphitheater, making it fairly easy to string the required cables under the seats within a row, within one section. Connecting that group, however, required drilling a hole through a thick concrete floor. Rather than bringing 14 cables through the hole, I designed a gathering station that administers all the seats in a row, and was then connected through the floor with a 15 wire cable to a higher level substation. Six of these were in turn connected to a central distribution point, which was connected by a long cable to the instructor's lectern. The lectern contains a central controller attached to a parallel I/O card in an IBM compatible computer, which runs the program controlling the system and interacting with the instructor. This computer is connected to a projector, enabling the instructor to show the results to the class when appropriate. Much more detailed information about the architecture of the system is available on the world wide web (Shapiro) or directly from me.

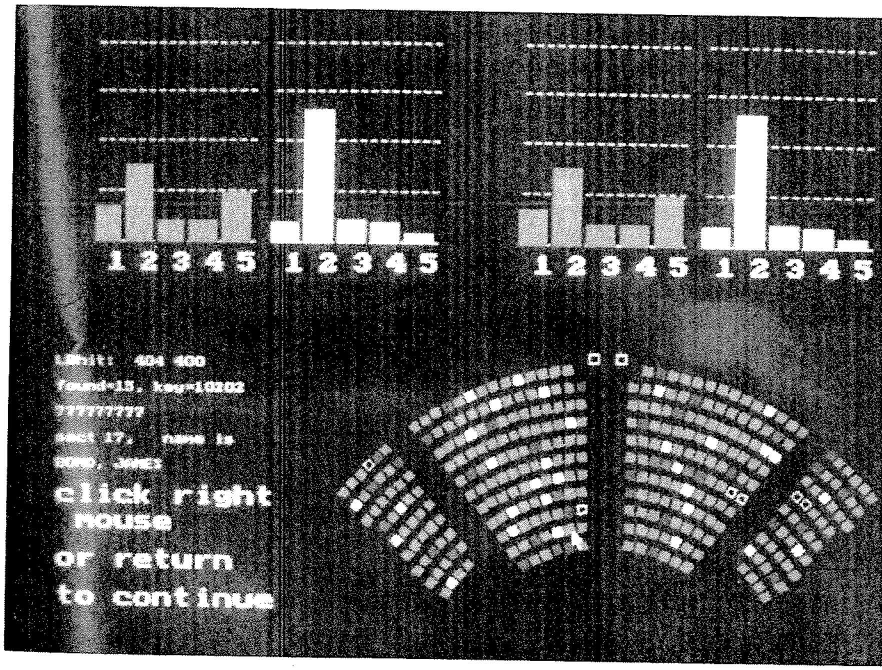

PHOTO BY JOEL SHAPIRO

A sample computer screen displaying seats in a lecture hall and multiple-choice responses for each seat.

CURRENT STATUS AND PLANS

The system hardware was designed over a two-year period and built and installed during 1995. By the beginning of the summer, one central sector, about a third of the lecture hall, was completed, and the system was used successfully by a medium-sized class during the summer session. The class employed only the multiple-choice anonymous mode.

At the end of the summer, the hardware for the rest of the 330 seats was installed. We also wired two additional outlets and have portable stations available for wheelchair use. The full hardware system has now been successfully tested. During the fall semester, the system was used in seven of the 10 physics classes taught in the auditorium. In five of these, the instructors utilized the tagged mode to take attendance and/or give quizzes. A program was hurriedly developed to meet this demand, but it was not found dependable until the end of the semester.

Two of the instructors used the system in an anonymous multiple-choice mode. They projected histograms of the responses, both before and after a brief discussion period, so that the students could see that their responses were acknowledged. They reported that the students liked using the system and remained attentive throughout the lecture. Two other instructors used it in the tagged mode solely to take attendance, with students entering their identification numbers at the beginning of class. The other three also used it in tagged mode, but for quizzes as well. Once the students entered their student numbers, their attendance and responses to any subsequent multiple-choice questions were recorded for grading purposes. The student numbers on the roster are available electronically so the system also provides a method of checking and resolving the discrepancy that generally exists at the beginning of term between the official rosters and the actual attendance.

Another function of the system displays all the seats in the hall and shows the multiple-choice response, or lack of one, by color for each seat. During attendance, it shows the seats that have returned a number. By using the mouse to select a seat on the screen, information is provided that allows the instructor to call on individuals by name. If we can acquire pictures of the students, the system might be able to show the picture of the student selected and enable the instructor to check for substitute exam-takers.

One advantage of a homemade system is that we have complete flexibility about what to do with the system, subject only to the limitations of the interface. We will be asking the instructors of the large courses to think of different ways to use the system, and will try to provide programming support to implement those ideas. Of course, many instructors simply want to use a canned program with explicit instructions, and we have provided two of these.

The most severe limitation of our system is the restriction of feedback to three lights. Some of the commercial systems have much better feedback mechanisms, such as a 16 character LCD display, or even multiline displays. I am not convinced that feedback in English, which some of these systems emphasize, is essential, but the ability to see the entered keystrokes or to provide some numerical response would be very helpful. For example, I do not think that the very limited feedback in our system is adequate to handle multiple-question exams because students have no reliable and simple way of returning to a previous question. A system that could verify a student is changing the answer on question 7 after entering the answer to question 10 would permit this. Even with our limited system, however, a quiz with a single multiple-choice question should function. Despite its limitations, our system will prove, I believe, to be a very powerful teaching tool.

DISSEMINATION

One of the major hurdles to implementing the new teaching tool is disseminating information about the system. Busy faculty members must be urged to put aside time to see what the system can do and investigate how to use it. Two of the three instructors who did not use the system said it was because they had not heard enough about it. Even though we have made the system available in a mode that is very easy to use, there is still inertia to overcome. Also, our department needs to have a staff member who can set up the system before each lecture so that the instructor does not have to worry about the hardware connections.

While I have provided detailed instructions on using the programs, the instructors still want to be walked through the use of the system. Fortunately this is possible. However, some thought has be given to providing this walk-through via electronic means in the future.

Instructions for using the system are currently available on the world wide web, and eventually a video walk-through may be available on the web as well. ❑

Acknowledgements

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RESPONDEXs interactive classroom from HMH Associates.