Using Wireless Keypads in Lecture Classes

Ray A. Burnstein, Illinois Institute of Technology, Chicago, IL 60616;
Leon M. Lederman, Illinois Institute of Technology, Chicago, IL 60616 and
Illinois Math-Science Academy, Aurora, IL 60506

We started to revitalize the physics lecture at our institution over five years ago by involving the students more in the lecture itself. It was our belief that the introductory lectures in physics as traditionally presented were ineffective. This was largely due to the size of the classes, rarely fewer than 40 students and in some cases as many as several hundred. The financial problems in both private and public universities made it safe to predict that the class-size problem would only get worse. Hewitt and Seymour[1] studied the dropout rate among first-year science and engineering students and noted that this is about 50% across disciplines. Blame for this unfortunate loss of students was most often attributed to the large, impersonal lecture format rather than to the subject being taught.

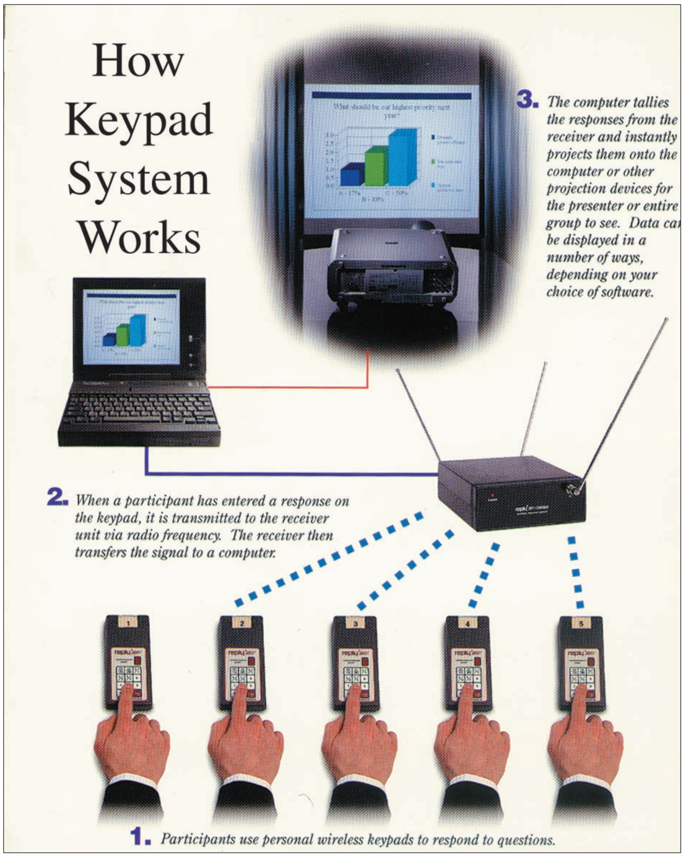

Fig. 1. Illustration of operation of wireless keypad system. *(Photo: Fleetwood Group, Inc.)*

We wanted to improve the lecture experience by actively involving the students more in the lecture itself. Reasons for the reluctance of students to respond in a large lecture were understandable. Recent articles by Hake[2] and Poulis[3] furnish data to support our approach and have established the value of modifying the passive lecture with "interactive engagement." Although many suggestions and innovations have been proposed and tried,[4-15] there had not been a solution to the problem of the passive large lecture proven to be successful, flexible, and cost-effective for a wide variety of students.

Our Keypad System

The procedure we initiated at the Illinois Institute of Technology (IIT) five years ago to enhance the participation of students in the lecture was by means of an *interactive student response system*. We used a commercial, two-way wireless (RF) keypad that the student can hold in hand and enter responses upon request during the lecture.[12] The results can be saved and displayed to the instructor or class or both within seconds. Figure 1 illustrates the keypad system and its operation.

We have made use of the wireless keypads in our elementary physics classes since the spring 1995 semester. With an average of 55 in each class, students were assigned a numbered keypad for the course.[16] Before each class, they exchanged their ID card for a keypad. Questions that could be answered by "yes"/"no" or multiple choice (1-10) were woven into the lecture and made relevant to what just happened or what was just about to happen. There were also questions to test whether students prepared for class. When appropriate, peer instruction[12,13] was encouraged by asking students to rework a keypad question through discussion with their teammates (usually two others) and arrive at a consensual response. All questions were displayed on a screen via an LCD overhead projector. Students were given from 10 seconds to a few minutes (depending on the complexity of the problem) to key in responses, which were picked up by an RF receiver and input to a personal computer program.[17] Results appeared within seconds by projecting a histogram of class responses. A later computer readout or printout recorded the performance of each student. These results were saved on a spreadsheet; the scores were available for inspection or grading purposes.

Our first year's experience was positive in spite of a good number of startup bugs and inexperience in "weaving" questions into the lecture. The lecture does cover less material and the process does initially put a burden on the lecturer. Even in the beginning, student acceptance was surprisingly tolerant and the keypad system always did receive a majority of positive votes. Students had to be alert with their minds on the lecture or demonstration material but did not seem to object. In effect, attendance and attention were being monitored.

After the first year, with a proven system, we made the keypad classroom an important and well-advertised factor in the course grade. In particular, we announced at the beginning of the semester that the keypads would count as some substantial part (15-25%) of the final grade. For each question, a correct answer earned the student 10 points, any answer earned three points, and no answer received zero points. With an average of five to 10 questions for each class session, a maximum semester score of over 2000 points had clear statistical significance. The weighting of homework problem scores in the final grade was reduced since keypad questions could test students on their mastery of homework concepts as well as their reading of the text before the lecture. Good preparation prior to lecture has produced improved student performance, as reported by Beichner[18] and others.[13] Keypad questions woven into the lecture also reinforce the lecture itself. Teamwork among students (peer instruction) was encouraged by including some team answers in the mix of questions.

A typical class session would begin with an outline of the topics to be covered and answers to student questions and then proceed to testing the students on their preparation for class with a few keypad questions. These focused on the concepts underlying the homework and on familiarity with the reading material. Then came the lecture, with keypad questions presented at the end of a topic or lecture module. All these activities did not fit easily into a conventional 50-minute class period. Fortuitously, the next semester the teaching schedules were changed so that two 75-minute classes replaced three 50-minute classes. This change is still in force. The keypad questions were of a wide variety and the questions could accommodate a broad range of instructional philosophies and goals. They allow an instructor to determine the following:

a) Have the students read the text before class?
b) Are the students paying attention?
c) Do the students remember important facts?
d) Are the students thinking?
e) Do the students recognize concepts?
f) Can the student work in a group?
g) Can the students do numerical exercises?
h) What do the students say about the pace and the interest of the lecture?

Instructors can evaluate and get feedback on their performance in "real time" using "How am I doing?"questions where students choose between, for example,

1) The lecture is very clear so far, no questions.
2) I have a question or two.
3) I have a lot of questions.
4) I am so confused, I don't have any questions.

Student response to the last question enables the teacher to extend, repeat, or modify previous lecture topic discussions.

All keypad questions do not necessarily need to be prepared in advance of the lecture. Certainly we feel that it is desirable; the result improves as questions are more carefully integrated into the lecture. However, the hardware and software allow the insertion of spontaneous questions into a set of prepared questions. For this reason we expect that a lecturer experienced with the system can, if appropriate, generate questions "on the fly." These are in fact often stimulated by class response to some previous question. The ability to weave questions into the lecture and generate impromptu questions probably takes a semester or so of experience. It is also possible to structure multiple-choice questions so that they simulate an essay question. The restriction to multiple-choice questions gave us a deeper understanding of this type of assessment. In more recent applications, we have experimented with partially correct answers and with even more than one correct answer. Of course students must be made aware of these options.

Hardware and Software

The basic ideas of a keypad response system outlined here are not new[19] and trials with prototype systems have been reported. Our system (see Fig. 1) is unique in that it is a two-way wireless, commercial system[20] and did not require much hardware or software development on our part to make it initially operational. We have been able to concentrate on using these tools to modify the lecture format instead of being involved with expensive and time-consuming hardware and software development.[17] The commercialization of the system, principally the wireless aspect, gives the response system a high degree of functionality and mobility that has, we believe, not been achieved previously.[19] In addition, since the keypads have not required repair in five years of operation (except for one replacement set of C-cell batteries), the amortized cost is reasonable.

Recently a low-cost wireless infrared (IR) system[21] has appeared on the market. We used this keypad system for a portion of a semester in a class of 40 students. The one-way feature means that users of the keypad have to verify that their signals are received by the system. This is accomplished when the keypad users see their numbers displayed on the screen among a running list of keypad numbers received. The one-way IR system operated satisfactorily, but we have no data on its long-term performance characteristics.

The hardware needed, besides the keypads and receiver, consists of a computer and an LCD projection panel driven by the computer. A large TV or monitor can replace the LCD panel. In the case of the two-way RF system, a laptop computer with a large display would be adequate for a smaller class. For a one-way system, a large screen is needed to display which keypad answers have been received. Our software programs are PC based, but it is frequently possible to use a Macintosh with a PC emulator, and there have been attempts to make Macintosh versions of some PC programs. All the wireless equipment is portable; we use a suitcase holding 40 keypads for transporting our RF system from building to building. To move 75 keypads, we have constructed a storage box on wheels. Larger portable storage units for keypads can be constructed or are available commercially.

An important consideration in selecting any response system is the question of reliability and resistance to tampering by students. Reliability, for one thing, implies that the keypad can be dropped numerous times from desk height and remain operational. Our RF system has survived numerous drop tests and five years of challenges from engineering students, and no one has succeeded in compromising or hacking the RF system we use. We do not carefully monitor the distribution and return of keypads, except that students are asked to leave their ID cards in the keypad storage slot and at the end of class reverse the procedure. Occasionally keypads are missing, but are apparently taken accidentally since they always are returned by the next lecture.

Comments from Experience

A wireless keypad response system has a great amount of flexibility based on the wide variety of questions that can be presented. Questions are at the discretion of the instructor and can range from conceptual questions as illustrated by Hestenes *et al.*[22,23] and Mazur[13] to factual questions. An additional important feature, at the discretion of the instructor, is the grading associated with the keypad responses. If the instructor chooses, the keypad scores do not have to count toward the course grade. On that level, the keypads are useful in monitoring attendance and the effectiveness of the lecture, as well as livening up the lecture environment. However, we find that when keypad scores count for greater than 15% of the term grade, there is a dramatic improvement in attendance that reaches the 80-90% level and, in addition, the students make genuine attempts to prepare for the reading quizzes and remain alert throughout the lecture period.

The use of keypads dramatically changes the typical one-way interaction between teacher and student in a short time and is a powerful learning tool for the instructor. It has also achieved our goal of greatly increasing the participation of students in the lecture class. The wireless feature makes this technology easily portable to any classroom.

The introductory lecture course is an integral part of the undergraduate college system and the problems that physics has (the failure of the lecture format itself and the loss of underprepared students) are shared by other disciplines. Therefore the interactive student response system we are using has applications to other disciplines. One of our colleagues has used it successfully in an introductory chemistry course. The principal barrier to further use and evaluation of keypad merits in our science courses is simply inertia on the part of faculty. Once this is overcome, we would be able to accumulate and evaluate data from classes taught with and without keypads by equally competent faculty under controlled conditions. This would allow a quantitative assessment of the improvement achievable using a keypad classroom. The discussion given here does not exhaust the many possible uses of such a response system, which we are refining, but should demonstrate to readers some of the potential ways this tool can be used to revitalize the undergraduate lecture environment.

Acknowledgments

We are grateful to Professor Rollin Dix for the initial loan of the system and to Irving and Sarah Footlik for funding the equipment purchase. This research was supported in part by an NSF DUE Grant.

References

1. N. Hewitt and E. Seymour, "Factors Contributing to High Attrition Rates Among Science and Engineering Undergraduate Majors," Alfred P. Sloan Foundation Report (1991).
2. R. Hake, "Interactive-engagement versus traditional methods—A six-thousand student study," *Am. J. Phys*. **66**, 64 (1998).
3. J. Poulis *et al.*, "Physics lecturing with audience paced feedback," *Am. J. Phys*. **66,** 439 (1998).
4. A.B. Arons, *A Guide to Introductory Physics Teaching* (Wiley, New York, 1990).
5. L.C. McDermott, "What we teach and what is learned—Closing the gap," *Am. J. Phys*. **59,** 301 (1991).
6. S. Tobias, "Revitalizing Undergraduate Science Education: Why Some Things Work and Most Don't," Tucson, AZ, Research Corp. (1992).
7. A. Van Heuvelen, "Learning to think like a physicist: A review of research based instructional strategies," *Am. J. Phys*. **59,** 10 (1991).
8. R.G. Fuller, "Using Interactive Lecture Methods to Teach Physics," (American Physical Society Forum on Education, Spring 1994) and references therein.
9. R. Littauer, "Instructional implications of a new low-cost electronic student response system," *Educ. Technol.* (Oct. 1972), p. 69.
10. H.T. Hudson, "Teaching physics to a large lecture section," *Phys. Teach.* **23**, 88 (1985).
11. D.R. Sokoloff, "Enhancing physics learning in lecture with interactive, microcomputer-based demonstrations," *AAPT Announcer* **20,** 917 (1995).
12. R.A. Burnstein and L.M. Lederman, "Report on Progress in Using a Wireless Keypad Response System," The Changing Role of Physics Departments in Modern Universities, in *Proceedings of the ICUPE* (College Park, MD, 1996). [See also *AAPT Announcer* meeting issues from Summer 1995, Summer 1996, Summer 1997, Winter 1998, Summer 1998, Winter 2000.]
13. E. Mazur, *Peer Instruction, A User's Manual and Concept Tests* (Prentice Hall,1997). For recent information on peer instruction and a variety of topics, see Mazur's World Wide Web server at Harvard.
14 J. Mestre *et al.,* "Turning passive lectures into interactive learning environments with a classroom communication system," *AAPT Announcer* **20,** 917 (1995).
15. D.E. Meltzer and K. Manivannian, "Promoting interactivity in physics lecture classes," *Phys. Teach.* **34,** 72 (1996) and references therein.
16. We have tested the system for up to 90 students, but in principle up to 250 students can be handled on one communication (COM) port. With additional COM ports and receivers, over 1000 students can be accommodated.
17. Axiom Inc., Salt Lake City, UT, has authored the software. We have no direct or indirect financial interest in this company or any other company referred to in this article.
18. R.J. Beichner, "Improving the effectiveness of large-attendance lectures with animation-rich lecture notes," *AAPT Announcer* **20**, 917 (1995).
19. Better Education Inc., 4824 George Washington Memorial Hwy., Yorktown, VA 23692.
20. Fleetwood Furniture Company, Holland, MI, manufactures the system shown in Fig. 1. Other companies market the same (RF) product using different packaging.
21. Varitronix, Hong Kong, China.
22. D. Hestenes, H. Wells, and G. Swackhamer, "Force concept inventory," *Phys. Teach.* **30**, 141 (1992).
23. D. Hestenes and H. Wells, "A mechanics baseline test," *Phys. Teach.* **30**, 159 (1992).