

AC 2007-633: LESSONS LEARNED USING ELECTRONIC RESPONDERS IN A POWER AND CONTROLS COURSE

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Lessons Learned Using Electronic Responders in a Power and Controls Course

Abstract

The use of electronic response pads in class has become somewhat popular over the past several years, both in K-12 as well as in higher education. Electronic response pads are tv-remote sized devices that allow students to enter answers to questions posed by the instructor. The author used one such system, the Classroom Performance System (CPS) by eInstruction, during the fall 2005 and fall 2006 semesters in a required, sophomore-level course on electric power and controls. The CPS response pads were used for attendance, some quizzes, review questions, surveys, and example problems during the course. Student opinion of the system during the first offering was quite poor; however, the students in the second offering had a better opinion regarding the CPS usage. This paper describes how the units can be used in class and some of the lessons learned from the use of the CPS units.

Introduction

For many years, the traditional mode of delivering material in the engineering classroom has been the lecture, wherein the instructor talks and the students take notes. Occasionally, students might be asked a question, but when answers don't come quickly, the instructor often answers the question. Today's students, however, are much more used to learning by doing and often have much shorter attention spans, which certainly don't last the 50 minutes of the typical class period. Research has consistently shown that active learning on the part of students results in superior learning and long-term retention of material¹⁻⁹. Active learning, as the name implies, means involving the students actively during the class. These activities might involve discussions of material, answering questions, working example problems, and other techniques¹. When activities are done with other students in teams, it is called cooperative learning.

Over the past several years, I have tried to incorporate active learning into my class sessions in a sophomore-level, required course in Electrical Power and Controls. However, the success was somewhat mixed, partly due to my own personality and partly due to student attitudes. The classes have had enrollments ranging from the mid 30s to the low 70s, but typically in the 40s. Such classes are large enough that some students feel they can hide or do other things during the class. This has been particularly true with the availability of wireless networking throughout the campus, as students may be taking notes on a laptop or they may be doing email or even chat sessions during class. In particular asking students to work through a problem results in some doing other things. In some classrooms, it is possible to move around and observe what students are doing, but in many classrooms, the seating is arranged (e.g., fixed, theater seating) so as to make it very difficult to move around once the students are in place with their bookbags, coats, etc. Thus, I often found it difficult to determine how well students were doing during the exercises and how many of them finished and how quickly they finished. As previously mentioned, asking questions of students often results in little response, even if they are asked to indicate agreement or disagreement with something. Generally, I attribute this to fear of being wrong in front of the other students.

Despite my personal difficulties incorporating active learning into my classes, I continued because I could observe student response to a 50 minute lecture and it was not a pretty sight. When the University began making an electronic response system readily available in most classrooms, I was very interested in trying it out as a means of keeping the students involved in the lessons.

Classroom Performance System (CPS) Responders

Over the past decade, there have been a number of classroom response systems introduced to the market. Generally, the model is that the students have a response unit (aka a clicker) that can send data to a receiver. The responses are then compiled by a software program and the results can be viewed in a variety of ways. Early systems relied on IR signals from the students' clickers; however, as with a television remote, that required line of sight between the student and the receiver. In addition, large classes might require more than one receiver and students would have to aim at the correct target. More recently, RF systems have been introduced, which eliminate most of the problems associated with IR systems. One such system is Classroom Performance System (CPS) by eInstruction¹⁰. This is the system that was chosen by _____ University and it will be briefly described before discussing how it was used in the class and some of the lessons that have been learned using it.

As mentioned before, the heart of the system is the student clickers. In the two years, I have been using them, they have evolved significantly. Figure 1 shows two versions of the student clicker units. The left one is the version 1.0 clicker. As can be seen in the figure, there are alphanumeric keys. The students can respond to multiple-choice questions or to numerical questions. The version 1 clicker has two LEDs (the two white dots above the A/1 key) that indicate when the device is connected and sending. One issue that students complained about with these clickers was that they could hit the wrong key and unknowingly send a wrong answer. That problem was addressed with the version 2.0 clicker, shown at the right side of Figure 2. This version includes an LCD display. When the student makes a choice (A, B, C or a number like 132.7, depending on the question), the response is shown on the LCD before the send button is clicked. This feature seemed to help quite a bit with student acceptance of the system. Clickers are sold through the bookstores for about \$20.00 (US).

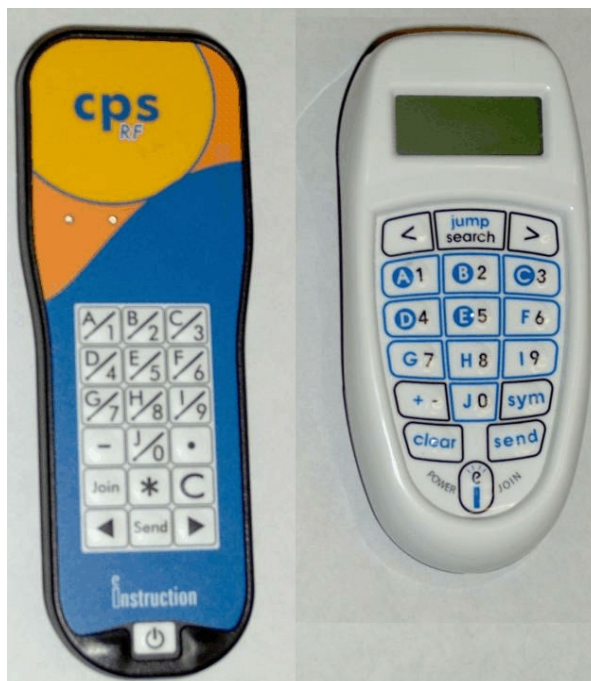


Figure 1: First and second generation RF response units

The system requires a classroom with a computer and projector. Questions are developed in the

question author module of the software provided as part of the system. Figure 2 shows the question author interface. On the right side is a portion of a drop-down box that allows the instructor to choose from a variety of question formats, including multiple-choice with two to eight choices, true-false, yes-no, and numeric responses. Questions are written in the top box of Figure 2 and answers are provided in the appropriate boxes below. As will be seen later in this paper, the system allows graphics to be used in the question statement or in the answers (up to multiple choice with five responses). Questions are grouped together as “lessons.” Lessons can be “Teacher-Managed” or “Student-Managed.” For example, questions during class would be teacher managed, as I would control how long they had to respond before moving on. On the other hand, quizzes were usually student-managed, which allowed students to progress through the quiz at their own pace and leave when they were done. Thus, I found it convenient to create a lesson for each class period with the questions that would be used during class and a separate lesson for a quiz. Note that student-managed lessons require a handout to the students with the questions and choices (if applicable), while teacher-managed questions are projected on the screen for the students to answer.

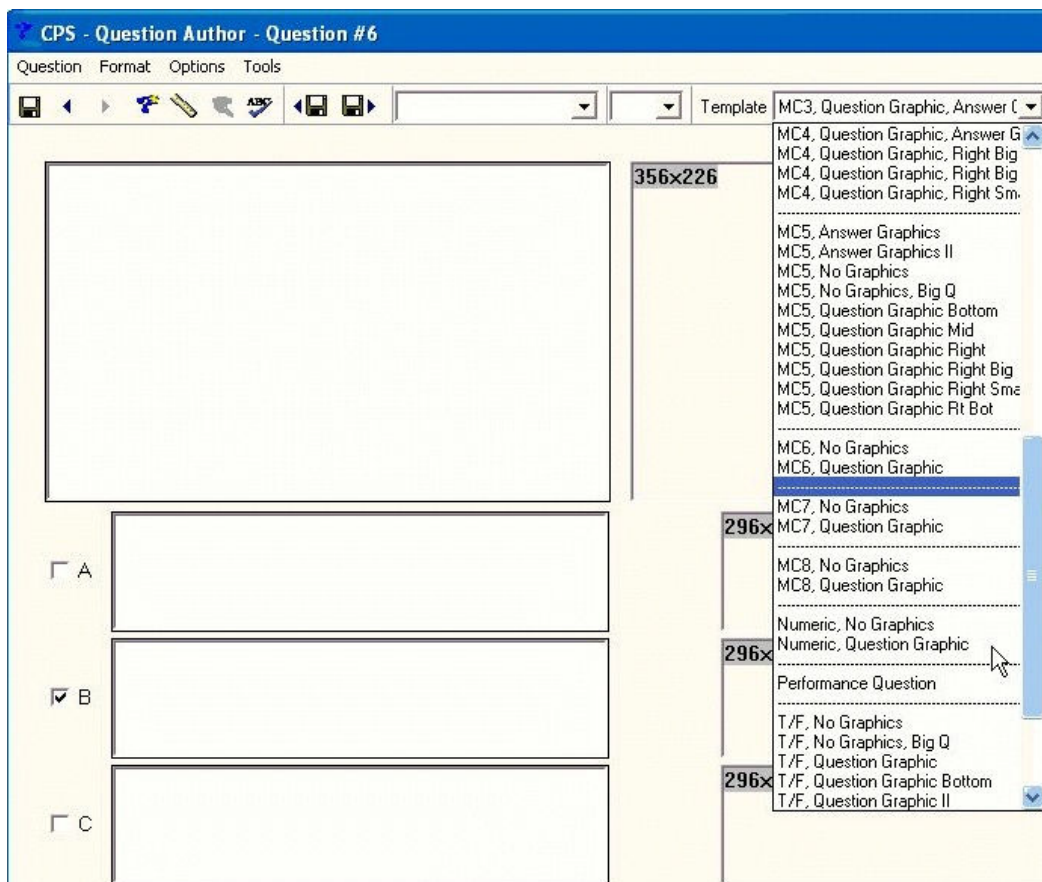


Figure 2: Interface for developing questions for student response

Obviously, for the system to be used for grading, there has to be an enrollment of the student clickers so the instructor and system know who is responding. At Purdue, enrollment is done through WebCT, which ensures that the students are registered using their email alias, rather than some unknown nickname. The University pays a fee for each course and student that uses the eInstruction system under a site licensing program. If a university doesn't have such an agreement with eInstruction, then enrollment is done through the eInstruction website with a charge to the student for each semester they use the clicker.

The CPS responders can be used for a number of functions in class including, but not limited to, the following:

- Attendance taking
- Review Questions
- Problem solving
- Quizzes
- Surveys

Attendance

One of the easiest uses of the responders is to maintain an automated attendance list. By selecting the attendance option, an attendance list is automatically created when the students log in with their clickers. If desired, points can be assigned for attendance and sent to a CSV file that can be read by a spreadsheet.

Review Questions

One of the strongest uses of the clickers in my opinion is for review questions during lectures. By asking questions and viewing the results, the instructor can gauge how well the students are understanding a concept. Just as importantly, students can see how well they are doing with respect to their peers, because if the instructor desires, the CPS software will display bar charts of the results after the question has been completed. Figure 3 shows a series of questions that were asked of students during the next class period after complex power was covered. The bar chart results have been superimposed on the question box to save space, but they would normally be displayed in a separate window after time has expired to answer the question (the instructor can set a countdown clock or can just end when he or she wishes).

The first question in Figure 3 (a.) asked what the product of voltage and current yields in an ac circuit, while the second (b.) asked which type of power is largest in a resistive-inductive circuit. Note that questions a., c., d., and e. utilize graphics as part of the questions and c., d., and e. use graphics in the answers. The correct answer to both a. and b. is apparent power, but in both cases half or more of the class chose an incorrect response. As a result, I immediately reviewed the power triangle to try to reinforce the concepts of real, reactive, and apparent power. Questions c., d., and e. involve a combination of circuit analysis with the concept of real power. Students tend to lock on to equations and don't think about their application; i.e., they forget that to find real power one must use the actual voltage or current in the resistor.

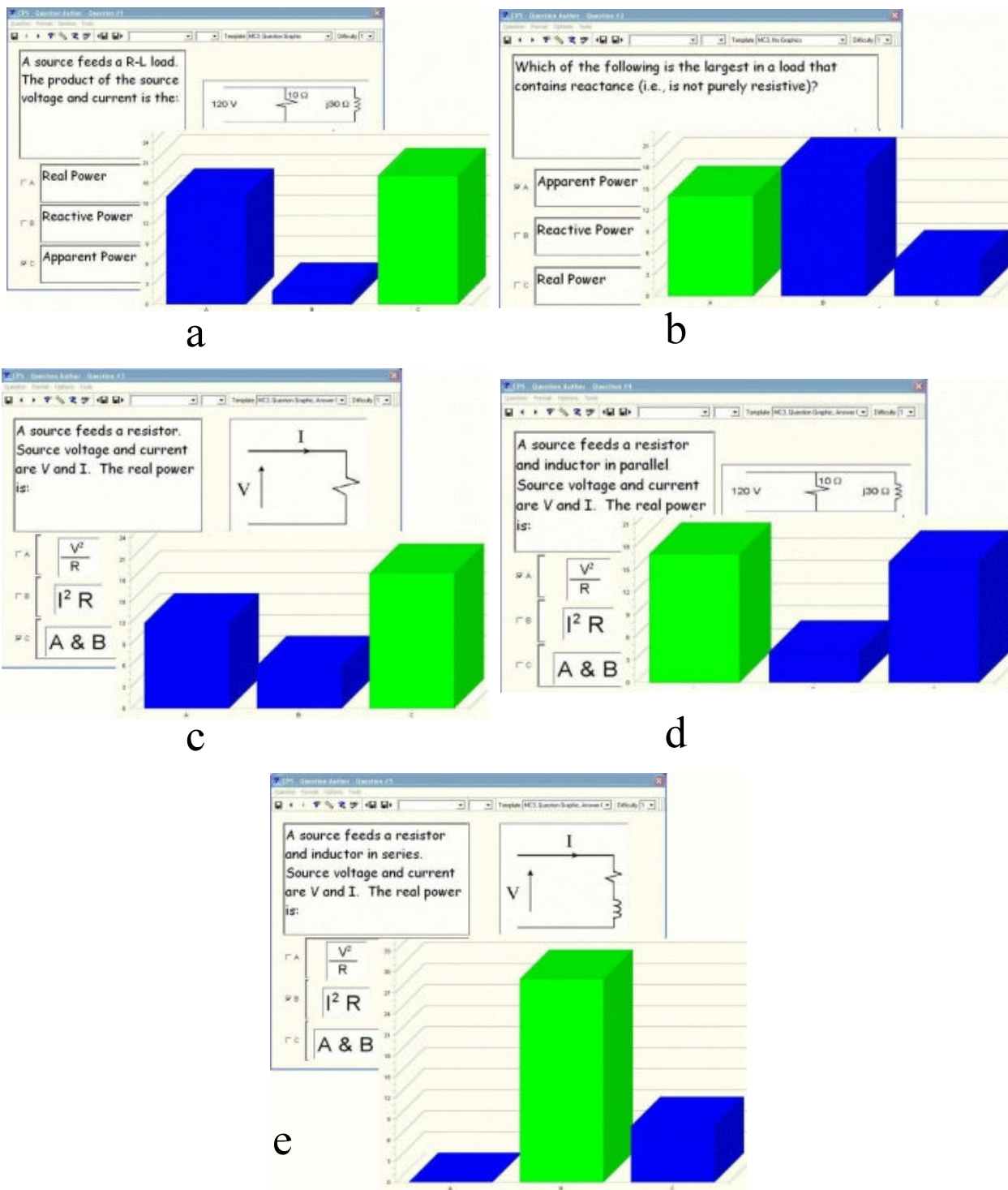


Figure 3: Examples of In-Class Review Questions and Results

In the first case (c.), the circuit is purely resistive, so the source voltage and current are the same as the resistor voltage and current. Thus, all three choices are correct, but answer c is the most correct since either formula can be used. About half the class chose the most appropriate answer.

For question d., the circuit consisted of a resistor and inductor in parallel, which means that the source current is no longer equal to the resistor current. Thus, V^2/R would have to be used to find the real power. Again only half the class chose the correct formula. I explained why choice b (and hence c as well) was incorrect. Finally, on question e., a series R-L circuit, a significant majority of the class chose the correct response, hopefully indicating they were starting to think about what they were doing.

Problem Solving

In a typical class (mine included) the professor works through example problems and the students copy them down without much thought. In previous years, I had occasionally asked the students to work through an example, but as previously mentioned, the results were somewhat inconsistent. With the responder system, I typically break problems up into several steps and ask the students to respond with an answer to each step. Sometimes, I give them multiple choice responses and sometimes I ask for a numerical response. Multiple choice can be advantageous when I know what types of mistakes the students typically make, as I can offer them choices using errors they might make. Then I can explain why they are wrong. The disadvantage of multiple choice is that some students may just guess rather than try to work through to a solution. Numerical answers require the student to work through the problem. If almost everyone gets the correct answer, I can move on. If not, I show how the calculation should have been done and hopefully the students can identify where they went wrong in their own calculations. When working examples, I encourage students to discuss their approach with their neighbors in class.

Quizzes

Quizzes can be given and scored automatically using the responder system. Like the example problems, they can be multiple-choice or numeric responses, depending on the material being covered. One thing that I quickly learned was cheating is much easier with multiple choice questions. Fortunately, the CPS software allows the use of multiple forms for quizzes. I found it convenient to use three or four forms for each quiz. Generally, the only difference was shuffling of the order of the questions or of the multiple-choice responses. When numeric responses were used, then slight changes to the given data could be used to result in different answers for each form, with no change in difficulty (i.e., no form of the quiz was any easier). The results of quizzes can be saved to CSV files and rapidly imported into a spreadsheet or other grading program.

Surveys

In addition to responses that are scored by student, anonymous surveys can also be conducted with electronic responders. This can be useful for collecting assessment data for ABET accreditation or for other scholarly pursuits. As an example, a paper last year provided results of students' attitudes towards ethics issues¹¹. Sixteen questions from the paper (Table 1) were put into the CPS software and 35 students were surveyed following a discussion of the Enron scandal and its effects on the energy business. Using the responders, I was able to obtain responses to the 16 questions in five or six minutes and the software provided me with a report of

Table 1: Questions for Results Reported in Figure 4
1. It is important for me to receive some formal ethics training during my college career
2. It is important for engineers to be aware they may encounter ethical conflicts in the workplace
3. It is important for engineers to actively anticipate potential ethical conflicts
4. I would benefit from training in ethics
5. I will encounter ethical dilemmas in my career.
6. I have encountered ethical dilemmas in school or at work
7. If a person clearly understands ethical standards, then solutions to most ethical conflicts can be readily ascertained
8. There is often a right way and a wrong way to resolve an ethical conflict
9. As long as I do my job the way it's supposed to be done, I won't experience ethical conflicts
10. One's religious beliefs should be the primary consideration when trying to resolve an ethical conflict
11. One's personal well being should be the primary consideration when trying to resolve an ethical conflict
12. The best interests of the employer should be the primary consideration when trying to resolve an ethical conflict
13. The overall good of everyone should be the primary consideration when trying to resolve an ethical conflict
14. Minimizing financial loss should be the primary consideration when trying to resolve an ethical conflict
15. The primary consideration when trying to resolve an ethical conflict will vary from situation to situation
16. A code of ethics for engineers would be useful to have

the results, shown in Figure 4. The responses A through E, correspond to Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree. The paper provided results corresponding to the total column of Figure 4, which is a weighted average of the responses (A=1, B=2, etc.). With these results, I can compare my students attitudes to the students reported in the paper and potentially include this as evidence for ABET. By way of note, most of the results were similar, although my students generally scored a bit lower than the reported results. I attribute this to the fact that my students were surveyed after a one-hour case study, while the reported groups participated in a six-week program, involving a three-hour case study and three writing assignments.

I also used the clickers to compare student attitudes toward energy usage and global warming to results published in Time magazine. In some cases my students' opinions were considerably different than the general population. One student asked why—I surmised that students are younger and more educated than the general population, which would probably affect their attitudes and beliefs. Having looked at some ways of using the responders, I will now consider some of their advantages and disadvantages.

Opinion Survey

Session: Lecture 04 survey

Class: ECET 231 - Electrical Power And Controls - ECET 231 - T Skvarenina - Fa06

Question:	N/A	A(1)	B(2)	C(3)	D(4)	E(5)	F(6)	G(7)	H(8)	Total
1	2 (6%)	2 (6%)	1 (3%)	7 (20%)	14 (40%)	9 (26%)	0 (0%)	0 (0%)	0 (0%)	3.82
2	1 (3%)	0 (0%)	0 (0%)	1 (3%)	22 (63%)	11 (31%)	0 (0%)	0 (0%)	0 (0%)	4.29
3	1 (3%)	0 (0%)	1 (3%)	5 (14%)	22 (63%)	6 (17%)	0 (0%)	0 (0%)	0 (0%)	3.97
4	0 (0%)	1 (3%)	1 (3%)	12 (34%)	19 (54%)	2 (6%)	0 (0%)	0 (0%)	0 (0%)	3.57
5	0 (0%)	0 (0%)	2 (6%)	6 (17%)	15 (43%)	12 (34%)	0 (0%)	0 (0%)	0 (0%)	4.06
6	0 (0%)	1 (3%)	1 (3%)	2 (6%)	22 (63%)	9 (26%)	0 (0%)	0 (0%)	0 (0%)	4.06
7	0 (0%)	2 (6%)	9 (26%)	7 (20%)	16 (46%)	1 (3%)	0 (0%)	0 (0%)	0 (0%)	3.14
8	0 (0%)	5 (14%)	6 (17%)	9 (26%)	12 (34%)	3 (9%)	0 (0%)	0 (0%)	0 (0%)	3.06
9	0 (0%)	8 (23%)	16 (46%)	3 (9%)	4 (11%)	4 (11%)	0 (0%)	0 (0%)	0 (0%)	2.43
10	0 (0%)	15 (43%)	12 (34%)	5 (14%)	1 (3%)	2 (6%)	0 (0%)	0 (0%)	0 (0%)	1.94
11	0 (0%)	5 (14%)	13 (37%)	7 (20%)	8 (23%)	2 (6%)	0 (0%)	0 (0%)	0 (0%)	2.69
12	0 (0%)	10 (29%)	16 (46%)	5 (14%)	3 (9%)	1 (3%)	0 (0%)	0 (0%)	0 (0%)	2.11
13	0 (0%)	2 (6%)	1 (3%)	4 (11%)	13 (37%)	15 (43%)	0 (0%)	0 (0%)	0 (0%)	4.09
14	0 (0%)	6 (17%)	9 (26%)	11 (31%)	8 (23%)	1 (3%)	0 (0%)	0 (0%)	0 (0%)	2.69
15	0 (0%)	1 (3%)	1 (3%)	1 (3%)	17 (49%)	15 (43%)	0 (0%)	0 (0%)	0 (0%)	4.26
16	0 (0%)	1 (3%)	0 (0%)	2 (6%)	16 (46%)	16 (46%)	0 (0%)	0 (0%)	0 (0%)	4.31

Figure 4: Results of an Anonymous Survey of Students Attitudes Toward Ethical Issues

Advantages of Using Electronic Response Systems

Chickering and Gamson¹² described seven principles for good practice in undergraduate education. In particular, they stated that:

“Good practice in undergraduate education:

1. Encourages contacts between students and faculty.
2. Develops reciprocity and cooperation among students.
3. Uses active learning techniques.
4. Gives prompt feedback.
5. Emphasizes time on task.
6. Communicates high expectations.
7. Respects diverse talents and ways of learning.”

Consider how these can be aided by the use of electronic clickers. The first principle is that education should encourage contact between students and faculty. Obviously, interaction cannot

occur unless students come to class. Using the clickers can improve class attendance, if the results are used as part of the students' grades. In particular, I counted classroom participation and quizzes for about 15% of their final grade. In addition, once the students were in class, they were more actively engaged as they were required to calculate answers and think about what was being asked. I found them more likely to ask questions when they had been working on something rather than just watching it being done.

The second principle says that good practice develops cooperation among students. While I hadn't initially thought about it, students rapidly began talking to each other when doing example calculations. I decided that was a good thing, since the goal is for everyone to understand how to do the calculations and to think about how to solve problems. As previously mentioned, when students didn't get it, as indicated by a high percentage of wrong answers, I was able to provide explanations of how to do the calculation as well as why the wrong answers were wrong. For example, in three-phase power calculations, they might forget the square root of three factor and I could point out that their answer was off by that factor.

The third principle is the use of active learning and the fourth emphasizes prompt feedback. While it is clearly possible to incorporate active learning without the clickers, I have found it much easier to do so with clickers. By counting responses for credit, students are forced to participate. The ability to demonstrate the class results immediately is very useful. When 90% of the students have the correct answer, the other 10% know they need to work a bit more on the topic at hand. Conversely, when a high percentage don't get the correct answer, I know I need to revisit the topic or provide a better explanation.

The fifth principle is time on task. One feature of the clicker system is a timer for questions. By setting a timer the students know how long I think it should take them to calculate an answer. The system also shows who has answered (by number not name) so if a student sees that 75% of the class has answered and he or she is still struggling, it is a good indication that more personal work is required. Again, if I find that students are not answering in a reasonable time, I know I need to explain the topic in more detail.

The sixth principle is to communicate high expectations. By requiring students to work examples, I believe I am teaching them that I am not going to spoon feed them and that it is their responsibility to learn the material. The teacher becomes more of a guide and coach.

Finally, the seventh principle is to respect diverse talents and ways of learning. Certainly some students can learn from listening to a lecture, but others require interaction with other students and "hands-on" exercises during classes. The use of the clickers allows time for student practice and interaction.

Disadvantages of Electronic Response Systems

The primary disadvantage of the clicker systems for schools that haven't adopted the technology is cost and support. At Purdue, the receivers have been installed in every classroom on campus that has a computer and projector. The receivers cost money, and with the large number installed

there is at least one full-time individual assigned to support the system. Also, the University pays the subscription fees for the use of the clickers each semester. Thus, the only cost is to the student to obtain a clicker for about \$20 at one of the bookstores. For a professor at a school that doesn't have a site agreement, my understanding is that it would be possible to obtain a receiver at low-to-zero cost and then the students would have to pay for the clickers and the subscription fees.

Another disadvantage of the system is that students tend to dislike it. They are being held responsible for coming to class every time and participating in class. They would much rather be free to skip class when they want to and get the notes off the web or from a friend. With the first class I taught using clickers, this was a major issue and was reflected in the end-of-term evaluations. In the conclusions section, I will describe how I tried to deal with that with my second class.

The final disadvantage, that I have found is that it takes time to develop good questions and multiple choice responses for use in class. The numeric format of the clickers only allows a single number to be entered, so numeric problems must be structured to allow the students to enter the numbers in a reasonable format (e.g., rather than asking for an answer of 345,000 Volts, it would be preferable to ask for the answer in kV so students could merely enter 345). However, students that don't pay close attention to the requested format of the answer might wind up inputting the wrong number (345,000) when kV is requested.

Conclusions and Lessons Learned

During the first semester that I used the clickers, I had a very negative response, which I believe was propagated by a few students. They seemed to feel that by asking them to work examples, I was forcing them to do things they hadn't seen before. Generally, that wasn't the case, but even where it was I saw that as a good thing. Their problem really revolved around the counting of their answers in their grade. While I hadn't explicitly discussed it, I was awarding them 50 to 70% credit for attempting the problems and providing an answer. The second time I used the clickers in the course, I explained up front that the purpose of using the clickers for class participation was to involve them and help them to learn and that they would receive 7 points for attempted (incorrect) answers and 10 points for correct answers. Of course for quizzes, they only received credit for correct answers. Quizzes and class participation were combined as a single grade category, which resulted in class participation being worth about 10% and quizzes about 5% of the final grade. This resulted in a much better attitude toward the clickers (and the course/instructor) during the second class. Another factor that helped with acceptance of the clickers was the second generation clicker, shown in Figure 1, that displayed the student's answer before it was sent.

I found that surveys could be conducted only if they were instructor-managed rather than student-managed. With the ethics and energy/global warming surveys, the students were very interested in seeing how their personal responses compared to the class or to other groups. Unfortunately, if the survey was not of great interest to the students, they didn't take it seriously, especially if it was student-managed. In particular, I gave out a survey on paper at the end of the course

concerning achievement of course outcome and asked the students to complete them anonymously at their own pace. I immediately observed some students racing through the responses, typing “C” (neutral) for every question so they could leave class a couple minutes early.

Students indicated after the anonymous surveys on ethics that it was kind of fun to give anonymous results. So one day I tried letting them answer the class participation questions anonymously, but I found they were answering more incorrectly. On about the third question, I overheard one student asking another about the answer choices, and the second student said, “it doesn’t matter.” As a result, I only recommend anonymous responses for opinion surveys.

As indicated above, I used the clickers in classes with 35-45 students. I also tried them in an upper-division elective class of 10 students. I rapidly found it wasn’t worth the time to develop questions for a small class and that it was much easier to use traditional active learning techniques. With a small number of students, it was easy to walk around them and watch what they were doing and answer questions.

In conclusion, I have found that the use of electronic responders (clickers) has enabled me to more easily incorporate active learning into my classroom sessions. They also facilitate grading of quizzes and collection/analysis of survey data. I believe it is necessary to include results from the clicker responses in the course grading scheme or the students won’t take them seriously. On the other hand, the clickers shouldn’t be seen as a threat to their grade. Finally, the design of the questions is extremely important and can be time consuming. Thus, the clickers are most valuable in larger classes.

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