The Use of Clickers in Engineering Classrooms

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As emphasized by many studies, cooperative learning can improve engineering education (1,2). One form this has taken in Physics and Chemistry departments is in-class ConcepTests (3,4). These are multiple-choice conceptual questions posed to the class. After all the students respond with an answer, they are asked to discuss the answers amongst themselves (peer instruction), and then given the opportunity to change their answer.

Mazur (3) showed a lack of correlation between student's conceptual understanding of physics and their ability to do quantitative problems. Students could do quantitative problems better than conceptual problems that used the same concept. He stated that students memorized algorithms for solving the problems without understanding the concepts, and thus had difficulty when the problem they had to solve was different from ones they had solved previously. He reported a gain in student performance with the use of ConcepTests. The students' conceptual understanding increased because students were better able to explain concepts to one another than their teachers could. The percentage of students with the correct answer always increased after they discussed the question with their neighbors .

The effectiveness of ConcepTests can be improved if students are graded on their answer, because this increases both participation and motivation. The grading is done with IR transmitters and receivers, as described below. Our experiences in engineering courses showed the following advantages:

- students liked using concept tests and getting instant feedback on how well they understand material as it is presented to them.
- the instructor obtained instant feedback on how well the class understood a concept.
- students are more motivated to be prepared and thus they learn more in class.
- attendance in class was higher than the previous semesters where ConcepTests were not used. Though statistics were not obtained the previous semesters, attendance was over 90% when ConcepTests were used and graded.

- everyone participated in class
- the discussions among students were quite lively at times. Students interact and teach and learn from their fellow students. This creates a more engaged class and students hear more than one explanation. It increases learning.

The use of clickers has been expanded to include multiple choice quizzes, teaching steps in problem solving, predicting outcomes in demos, and involving the students in the curriculum. This brief article describes the relatively-inexpensive technology available for clickers and examples used in our classrooms. Examples used for sophomore, junior and senior level Chemical Engineering courses will be presented, and feedback discussed. Finally, a summary of advantages and disadvantages of the system are presented.

Explanation of Clicker Use

Learning with transmitters (clickers) works as follows:

1. The instructor poses a question and presents possible answers (multiple choice).
2. Each student picks an answer by select A,B,C,D,E on the clicker
3. The instructor displays at a histogram of answers for the class to see. If most answers are correct, a short explanation is given and the next topic is started.
4. If many answers are incorrect, students are told to discuss the question with their neighbors. This peer instruction is a critical aspect of learning. It fosters student involvement and engagement.
5. Students are allowed to change their answers after the discussion. Thus, most of the students end up with the correct answer and a better understanding.
6. If most students have the correct answer, a brief explanation is given. If not, the question is discussed more, and the instructor provides additional ideas to help learn the concept.

Receivers are mounted high on the walls in the room, one per approximately twenty students. The receivers are small (3.5 x 2.5 x 1.5 cm) and are daisy-chained together by cables. The cost of 3 receivers and cables is around $600. The receivers collect the signals and send them to a PC running the H-ITT acquisition program.. The software that collected the student responses was downloaded free from the H-ITT web site (5). Each student has their own hand-held transmitter (clicker), purchased from the bookstore for $30. The H-ITT hand-held IR transmitter, similar to a TV remote control, has a unique ID number. The clicker is larger than a pen and battery operated.

Each student responds to the multiple-choice questions by aiming the clicker at a wall-mounted receivers and pressing A,B,C,D, or E. The H-ITT acquisition program display is also projected onto a screen for the entire class to see. The ID number (or the student initials) of each clicker is displayed indicating that the student response has been successfully collected, but it does not show the student answer. The H-ITT Acquisition program summarizes the data and displays the class responses in histogram form,.

After class, a separate program associates student names with the remote ID numbers and grades the responses instantly. It allows the instructor to assign point values to each answer for each question (e.g., 3 points for correct answer, 1 point for incorrect answer). The software also allows a list of the student names and point totals to be quickly exported into a spreadsheet.

First, examples of ConcepTest questions from a Thermodynamics class are presented. The use of clickers debuted in Thermodynamics and even though students could work numerical problems, many did not have a good grasp of the thermodynamic concept involved. For example, they could calculate the vapor pressure at a given temperature with Antoine's equation, but a large fraction of them did not understand the concept of vapor pressure well enough to answer questions like problem 2 below. For many of the ConcepTests used, more than half the class initially answered incorrectly, but the percentage correct increased, usually dramatically, after discussions with other students.

1) Components (A and B) are in vapor-liquid equilibrium. One mole of liquid ($x_A = 0.4$) and 0.1 mol of vapor ($y_A = 0.7$) are present (Fig. 1) When 0.5 mol of A is added and the system goes to equilibrium at the same T and P, what happens?

A. The amount of liquid increases

B. The amount of liquid decreases

C. The concentration of A in the gas phase increases

D. The concentration of A in the liquid phase increases

7) Water alone is present and is in VLE at 1.2 atm in a piston/cylinder. You inject 5 cm^3 of air into the system, but keep P and T constant. What happens?

A. All the water vaporizes

B. All the water condenses

C. Some water vaporizes

D. Some water condenses

Many students initially had problems answering these types of questions since some of them require higher levels of Bloom's taxonomy. These examples are presented to give the reader an idea of how ConcepTests are applied in class. Similar problems were then used on the course exams, but without the multiple choice options and with the requirement that the student explain the reason for their answer.

The use of clickers has been expanded to uses other than ConcepTests. In a sophomore-level Material and Energy Balances course, clickers were used to teach steps in problem-solving. A typical problem would be to solve for moles of CH_4 per mole of $CaCO_3$ converted in a reaction. Using traditional chalk-and-talk pedagogy, the instructor writes the steps on the blackboard, students passively copy the information, and the concept is sometimes learned. However, with the use of clickers, students become actively involved in the learning process. Every step is presented using multiple choice questions (for example, how many degrees of freedom does the problem have, how many independent reactions are there, etc.). This allows (even forces) the students to participate, as well as gives the instructor the opportunity to focus on the concepts that students miss along the way. In addition, the students do the calculations, rather than waiting for the instructor to solve the problem and then copying the answer.

In the capstone design course, students were assigned to select an article, present an overview to the class and then pose their own clicker question to the class. For example, an overview of an article on dust explosions was presented by one of the students. At the end, she gave this clicker question:

In order to prevent dust explosions from occurring as a result of ventilation systems:

(a) False ceilings should be eliminated in the design of the structure where such dusts are being handled

(b) SOPs should be in place to routinely do housekeeping in the ceiling area to remove collected dusts

(c) Specs should be in place regarding proper vacuum (cleaner) equipment permitted for picking up such dusts

(d) A literature search should be done to determine how others are handling such dusts

(e) All of the above

Explanation of the material and preparation of the clicker question compelled the student to thoroughly understand the article as she was graded on the number of students who got the clicker question correct.

Feedback from the students was overwhelmingly positive.

"The greatest part about it was that you made thermodynamics a fun class to attend."

"There was one thing in particular that I really enjoyed, and that was the clicker questions."

"I thought the overhead concept tests were a great idea, and a good usage of the clickers."

"Being able to immediately apply what we were learning and receive instantaneous feedback was fantastic."

"The transmitters were very effective as a learning experience.

"They gave support to myself in times when I felt unwilling to ask a question for fear I was the only one who didn't understand."

The concerns expressed by the students were small. The biggest concern was that they had to spend $30 to purchase a transmitter to only use in one course. Since they should be able to sell theirs to the students in next year's class, these should become less of a problem. Some students were concerned that the grading in every class forced them to come to class more.

Clickers have been used is classes at all levels and sizes as indicated by Table 1. One of the instructors has used clickers in classes outside the department with similar success.

Class	# students	Level
Chemistry for Engineers	400	freshman
Creative Technology	450	fresh/soph
Material & Energy Balances	75	soph
MechE Thermodynamics	35	soph
ChE Thermodynamics	55	junior
Heat Transfer	55	junior
Materials	65	junior/senior
Design	45	senior

Summary

Even though engineering students could work numerical problems, many did not have a good grasp of the concepts involved. The use of clickers has increased the comprehension in a relatively easy fashion as learning with clickers has many advantages over traditional lecture format. Students teach and learn from their fellow students which results in a more engaged class; the students are exposed to alternate explanations; the instructor gets instant feedback from everyone; the students are more motivated, and class attendance is higher. In addition, the H-ITT software was easy to use in class, and the students could readily see their clicker ID number on the projected display. (Since their ID number always appeared in the same location on the screen, it was easy to find). Potential concerns for use of this system include the amount of time needed to develop the clicker material and learn the system, as well as problems with cheating, particularly in large classes. However, once the initial outlay of time and effort are put in, using clickers in the engineering classroom is a simple and rewarding experience.

References

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