# AC 2008-1157: CLICKERS AND FRESHMAN ENGINEERING CLINIC

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# Clickers and Freshman Engineering Clinic

## Introduction

"Clickers" are gaining wide popularity at all levels of education, from K-12 to Universities. These electronic handheld devices communicate wirelessly with the instructor's laptop computer, which is used to project a multiple-choice question or quiz to the class. The students' responses are transmitted to the instructor via the clickers and the tallied result is provided nearly instantaneously in the form of a histogram. The students and the instructor receive immediate feedback on the students' state of learning and the instruction may be altered in a just-in-time fashion based on this information. Teachers and professors are enthusiastic about these devices because they promote student participation and classroom engagement and, if desired, they can be used as a form of graded assessment of student learning. Students enjoy using them in class because they help breakup the monotony of a long lecture and make the classes "fun."

In Fall 2007, the clickers were used in three sections of a Freshman Engineering Clinic, with approximately 60 students. The sections were taught by three different professors, two of whom were using this technology for the first time. Clickers were used to:

- Provide instantaneous feedback,
- Give and grade quizzes,
- Evaluate individual students' mastery of topics learned through participation in group projects, and
- Evaluate the organization and completeness of student portfolios.

This represents a wide range of clicker applications, from common to unusual. The purpose of this paper is to provide a brief background on clickers, describe the Engineering Clinic at Rowan University (especially the freshman clinic), describe the various clicker methods used in the Clinic, and evaluate the clicker applications based on instructor self-evaluation. The results of a survey of all faculty using clickers at Rowan University in Fall 2007 are also presented.

## Background

Clickers, also known as "classroom response systems" and by various trade names, are gaining wide acceptance in education. Although there are many vendors of clickers[1-3], each with different hardware and software features, nearly all of them operate in a similar fashion in the classroom. References (4) and (5) provide excellent general introductions to clicker use in education. They are used by faculty members in disciplines ranging from applied and social sciences to the liberal arts to professional schools such as law, medicine, business and engineering, and in a wide variety of applications. Clickers may be used to take attendance, score students for classroom participation, quizzing, or simply for providing ungraded feedback to engage students and encourage learning.

In the most common application mode for using clickers, each student is provided a clicker. The professor would present a new topic or concept for no more than 10 minutes using traditional lecture, demonstration, or sample problem solution. Thereafter, he or she would pose a skill or concept question to gauge the students' understanding. If the tallied responses show that a high

percentage of students do not understand the concept (low percentage of correct answer), the professor would further explain the topic since most students did not grasp the concept enough to help each other in this case. The key learning moment occurs when the responses show that a reasonable percentage of students understands the concept (a distribution of answers with a substantial number having the correct answer). In this case the professor directs the students to find a partner to explain the answer to each other (similar to the active-learning techniques known as TAPPS[6] or Think-Pair-Share[7]). Thereafter, the students are asked to either respond again to the same question or a different question on the same concept or skill may be posed. The final scenario occurs when student responses show a very high percentage of the correct answer, indicating that they understand the concept. In this case, the professor would briefly explain the correct solution and move on to the next topic.

The volume of literature that documents the research and applications of clicker use in the college classroom is rather large and growing rapidly (see Vanderbilt University's Center for Teaching's website[8] for a good compilation of the most recent articles concerning classroom response systems). This brief summary will be restricted to only previous literature reviews[9-13], which were broadly focused across a wide range of disciplines.

Fagen et al.[9] surveyed instructors who use a specific method of teaching called Peer Instruction[14], in which lectures are interspersed with short conceptual questions ("ConcepTests") designed to reveal common misunderstandings and to actively engage students in lecture courses. In nearly all cases, the instructors used a clicker system to gather the initial student responses, and then encouraged students to discuss the question in pairs. Finally, the instructor retested the students to gauge their conceptual understanding. The compiled results included 30 courses in physics, chemistry, life sciences, engineering and astronomy, and covered a broad array of institution types. Quantitative data gathered measured 'normalized gain'[15] for each course, and found that 90% of these achieved a normalized gain of 0.3 to 0.7, which Hake[15] previously found was only achievable by classes that used "interactive engagement" techniques. That is, this study found that use of clickers in a Peer Instruction environment appears to be a valid method of interactive engagement.

Roschelle et al.[10] also find a large base of supporting evidence for the positive learning outcomes achievable through the use of clickers. These outcomes include greater student engagement, increased understanding of subject, increased enjoyment of class, improved interactions, providing feedback to students of their state of understanding, and feedback to teachers of the students' difficulties. They report consistent findings across a range of university disciplines including physics, mathematics, chemistry, biology, premedical education, business and computer science. In the K-12 settings, they again find positive evidence of effectiveness in middle- and high-school mathematics, physics and chemistry, as well as in reading throughout primary and secondary education. The authors attribute these results to three factors: Increased use of formative assessment for feedback, which stimulates student reflections on their learning; building conceptual understanding using contrasts, both similar and different, and discussion; and motivating students to adopt mastery of learning as a goal, while avoiding the embarrassment of poor performance.

More recently, Fies and Marshall[11] reviewed the literature on clicker use in educational settings. In general, they found that while the vast literature is largely anecdotal or deals mainly with comparing clicker and non-clicker classes in which other factors are also unequal, there exists some evidence that clicker-enhanced classes do lead to quantifiable learning gains compared to traditional teaching modalities. They point out, however, that since clicker-enhanced classes are naturally an active-learning (or interactive engagement) environment, it is hard to isolate the effect of the clicker alone.

Preszler et al.[12] undertook a study across six biology courses, from lower to upper level, at one institution in order to measure student learning and attitudes toward the clickers. In summary, they found that students had an overall positive impression of the technology, and that they believed that clickers improved their interest in the course, their attendance, and their understanding of course content. The positive opinion was generally stronger in the lower-division courses than the upper-division courses. To measure the clickers' effect on student learning, the instructors varied the frequency of use of the clickers in each lecture throughout the semester. When tested, the students' performance on each question was compared to the frequency of clicker use (low, medium or high) during the lecture that covered the topic. The researchers found that increased clicker use was associated with improved performance in all six courses, lending more evidence to the efficacy of the clickers.

Caldwell[13] generally agrees with previous survey results that found clicker use in the classroom leads to improved student attitude, attendance, retention, and, perhaps, exam scores and student learning. She points out that the vast majority of the evidence that exists was not collected systematically enough to draw scientific conclusions, and it is possible that the alteration of the teaching methodology due to clicker use or even a 'Hawthorne effect' may be responsible for the positive findings. Caldwell points to three possible explanations for positive effects of clickers: (1) Increased active participation in class, (2) elimination of the 'house of cards' effect, in which students build poor new knowledge due to the existence of poor prior knowledge or misconception, and (3) use of discussions or peer learning.

**Engineering Clinic at Rowan University**

The four engineering programs at Rowan University (RU) have common Engineering Clinic classes throughout their programs of study. Students enroll in Clinics in each of their eight semesters at RU. Each clinic class involves students in teamwork (often interdisciplinary), hands-on activities, and report writing and presentation. For a more detailed discussion, see Reference (16).

The Freshman Clinic is focused on engineering measurements (Fall) and competitive assessment (Spring). The Sophomore Clinic is focused on engineering design. The course is team-taught with communications faculty[17-18]. Where possible, students write about and give speeches related to their engineering work. In Junior and Senior Clinics, students work in small teams of juniors and seniors on open-ended projects under the supervision of one or more professor. Each team works on a unique project, which can be multiple semesters in length. Most projects are funded by industry or governmental agencies. Typically, professors run two different projects each semester.

Because it is the focus of this paper, the Freshman Engineering Clinic (Freshman Clinic I) for the Fall semester is described in greater detail. Freshman Clinic I involves one 50-minute lecture and one 150-minute laboratory session each week. Students from all four disciplines are mixed in sections of approximately 20 students each. The course serves as both an introduction to college and an introduction to engineering. Lectures focus on survival skills and other topics important to freshman engineers, such as note taking, problem solving, engineering estimation, significant figures, professionalism and ethics. Approximately eight of the laboratory sessions are devoted to open-ended project-based learning used to reinforce lecture topics. The rest are used for exams, to view and discuss videos, etc.

Freshman Clinic I is additionally designated as a "Rowan Seminar" course. Rowan Seminar classes are university-wide courses designed to help freshmen adjust to college and to develop the skills required for academic success. The learning objectives of Rowan Seminar include:

- Classroom management skills
- Communication skills
- Critical thinking skills
- Library research skills
- Cooperative Learning

**Clicker Methods**

In Fall of 2007, clickers were used for the first time in three sections of Freshman Clinic I, sections 3, 4 and 6. Four other sections did not use clickers. The clickers used were i>clickers (www.iclicker.com). In sections 3 and 6, clickers were used for instantaneous feedback when teaching significant figures, unit conversions, and units of equations and graphs. The intent was to increase student involvement and stimulate in-class discussion. No grades were assigned when clickers were used when instantaneous feedback was the primary focus. In section 3, clickers were also used for pop quizzes on various course topics. In this case, grades were assigned using the clickers. In the same section, some pop quiz questions were used to test individual student's mastery of skills and knowledge that their team as a whole used to complete a given project. The purpose was to punish free riders and encourage significant participation in group work. Free riders are students that purposefully reduce their participation level, expecting that the other group members will compensate in order to obtain an acceptable grade, which the free rider will also receive. The Freshman Engineering Clinic also requires students to maintain an organized and comprehensive portfolio (including a detailed laboratory notebook record). In sections 3 and 4 the portfolio was evaluated at the end of the semester, at least in part, through a clicker quiz focused on the organization and completeness of the portfolio contents.

**Results**

***Instantaneous Feedback.*** Topics covered in Freshman Clinic I include making engineering approximations, applying measurement unit systems and conversions and reporting values to the appropriate number of significant figures. In previous offerings of the course, these topics and example problems were presented in traditional lecture and small-group problem-solving

approaches. Students self-reported that they often did not find the work interesting and commented that they already knew the subject material from prior experience and were thus bored. Yet homework, quiz and test scores indicated/revealed that student performance and mastery of the material was not on par with their verbal remarks.

Previous studies show that handheld computer-enabled rapid feedback, similar to that obtainable through clicker use, has a significant and positive effect on student performance when compared to no rapid feedback and students were positively receptive to rapid feedback in class and believed that it improved their learning in the course[19-20].

With the goals of engaging students and improving their ability to master topics such as unit conversion, significant figures and estimation, clickers were used to provide rapid feedback to students. In section 6, similar to the approach by Chen et al.[20] a 10 minute mini-lecture and example were presented. After which a multiple-choice question and 4 or 5 answers were posed to gauge student understanding. The students were allotted time to work out calculations if necessary and then asked to respond to the question using the clicker provided to each student. After the students responded, the professor displayed a histogram showing the number of responses to each of the answers. If the responses show a high percentage of misunderstanding, the professor elaborated then posed the question to be answered again. If responses showed a reasonable level of understanding, then the students were requested to discuss and then answer again. Once most students were able to answer correctly, a new question was presented and the process repeated.

The clickers were first used to promote the skills of correctly reporting units and computing unit conversions. For the first unit conversion question, only 30 percent of the students answered correctly. After being shown the histogram of responses, the students were asked to discuss and respond to the question again. The second time over 50 percent answered correctly, so the instructor presented the solution and the problem was worked and an answer given. A second unit conversion question was given and 81 percent answered correctly, a large improvement over the first question.

During another class period, computing numerical answers and reporting the appropriate number of significant figures was the topic for which the clickers were used. The number of correct responses increased from 81 to 100 percent on the first two questions.

In section 3, a PowerPoint lecture was used to cover unit conversion and significant figures. Clickers were used to obtain instantaneous feedback from students as they answered 7 questions related to the topics. For each question, the histogram of student answers was shown in class. Depending on the number of incorrect answers, additional lecture and discussion was used to improve student understanding before proceeding to the next question.

While class time in previous years was used for active learning, where students worked in pairs or small groups on the problems, using the clickers may have provided added incentive to work the problem since ALL students were requested to respond to the question and a histogram of student responses would be displayed. Thus, students were more engaged and interested during class time than previously.

While improvement in student performance is confounded by other factors such as repetition, discussion with classmates and in the case of quizzes and tests, studying outside of class, feedback by using clickers did serve as a vehicle to promote repetition and discussion.

***Pop Quizzes and Individual Mastery of Group Project Skills.*** In section 3 two pop quizzes were given with a total of 14 questions. Nine questions tested students on their understanding of topics covered in traditional lecture. Five questions tested students on their understanding of topics that they should have learned through participation in group-projects. In the first pop quiz, the average percentage of students correctly answering questions on lecture topics was 90. The average percentage of students correctly answering questions on group-project topics was 81. This was 92 and 54, respectively on the second pop quiz. Students that participated in class and in teamwork earned high grades on the quizzes. Furthermore, the quizzes were graded automatically, saving instructor-time. While the percentage of students correctly answering questions pertaining to individual mastery of group work decreased for the second quiz, this may have been caused by more difficult questions or more complex concepts being included in the second quiz.

***Portfolios***. Maintenance of an organized and comprehensive portfolio and laboratory notebook is a requirement of the course. This is directly related to the development of good classroom management skills and communication skills– good note taking and record keeping are particularly important in project-oriented work; logical organization and presentation are key to retrieval of information by the student and his or her team members. A complete portfolio would include lecture notes, homework assignments and solutions, quizzes, handouts, laboratory experiment handouts, a proper laboratory notebook, and project deliverables.

In previous years, the instructor teaching section 4 evaluated portfolios by inspection during or after the final exam. Students brought voluminous binders to the final exam, the instructors evaluated the portfolio for organization and completeness, and students received a score worth 5% of the final grade. In reality this method of evaluation was inconvenient, inefficient, and inadequate. It was difficult for the instructor to "spot check" a portfolio containing a semester's worth work and to evaluate it adequately. In addition, the instructor was left in possession of more than twenty heavy three-ring binders, which were diligently saved until the next semester, so students could retrieve their work when they returned to campus again. Typically, only about one student in ten returned to retrieve his/her portfolio. While portfolio materials are not specifically required in subsequent courses, they do contain resources that are generally valuable in all engineering coursework (e.g., guidelines for maintaining laboratory notebooks, writing technical reports, etc.).

Clickers were used for a new method of portfolio evaluation. The instructor developed a set of multiple-choice questions which covered all elements of the portfolio. The questions were geared strictly toward efficient information retrieval – these questions were not designed to challenge higher level thinking. A student with a complete and organized portfolio could quickly find the correct answer by looking it up in the appropriate section.

Portfolio quizzes were given at the mid-term and at the end of the semester. This format of questioning tested the student's ability to retrieve information from his or her own portfolio, and therefore was more closely aligned with the purpose of maintaining a portfolio in the first place. The average portfolio grade rose from 78% to 89% between the mid-term and the end of the semester, as students enhanced efforts to maintain complete portfolios. All students were in possession of their portfolios at the end of the semester, and hopefully will retain the material for use in Freshman Engineering Clinic II. The approximate time savings for the instructor was 2.5 hours.

In section 3, portfolios were evaluated only at the end of the semester. Portfolios were provided by individual students and project teams. Clickers were used to evaluate the individual portfolios in much the same way as described above. Fifteen of the 18 students in the section obtained a perfect score on their individual portfolios, indicating that they had included course materials in the portfolios in an organized manner. In the future, mid-term portfolio evaluations will be added to encourage better record keeping.

A survey was administered to five faculty members who used the clickers in seven separate classes during the Fall 2007 semester. The results for Freshman Engineering Clinic I are not reported separately since the data are so sparse. All five faculty members were new to using clickers, although one professor had some prior experience with a clicker-like system based on PocketPC handheld computers. All professors were broadly familiar with the concept of clickers and how they could be used in the classroom.

All but one of the courses was in engineering; the lone exception was from psychology. The classes ranged in size from 16 to 30 students, with some classes being freshmen only, graduate students only, juniors only, or a mix of seniors and graduate students. The faculty members reported widely different frequency of use, with a distribution varying from once per week to once per semester.

In general, the professors found the clickers to be easy to learn to use, and were extremely comfortable with them within two sessions of use. They found the clickers to require a non-negligible amount of set-up and clean-up time when used. The average of the responses to the question, "I lost some class time for content coverage when I used the clickers," was neutral (score of 2.71 out of a scale of 1=strongly disagree to 5=strongly agree), but the distribution of responses spanned the entire range. The two most important findings are that (1) the professors were unanimous in strong agreement that the clickers increased student engagement with the class material, and (2) the faculty members' overall impression was that the students enjoyed using the clickers in class. The quantitative results from the survey are provided in Table 1.

Table 1: Survey results from faculty members. Scale range ranges from 1 to 5, with the definitions of 1=strongly disagree, 3=neither agree nor disagree, 5=strongly agree.

| Question | Average score |
|---|---|
| The 'learning curve' for using the clickers was steep. | 1.29 |
| I was comfortable with using the clickers in class within two sessions. | 4.86 |
| Set-up and clean-up times were significant when I used the clickers. | 1.86 |
| I lost some class time for content coverage when I used the clickers. | 2.71 |
| The clickers increased student engagement with the class material. | 4.86 |
| Overall, my impression was that the students enjoyed using the clickers. | 4.43 |

When probed about their methods of use of the clickers in the classroom, the results showed a wide variation from faculty to faculty. The three most popular uses are:

- for informational feedback to students;
- for gauging students' understanding of class material in ungraded quizzing; and
- for graded quizzing.

**Conclusions**

By using clickers for feedback, students were more engaged and interested during class time than in previous offerings of Freshman Clinic I. An additional benefit for the students was that seeing the histogram promoted discussion and debate about assumptions that were made and the effect of the assumptions upon the final answer.

Clickers provide an efficient and convenient method for administering and grading pop quizzes, including the evaluation of individual student's mastery of topics learning during group work. However, the decrease in the student's score on individual mastery questions from the first to the second pop quiz indicates that either the pop quizzes did not encourage free riders to participate more activity or the questions/concepts included in the second quiz were more difficult.

Clickers provided an efficient and convenient way to evaluate student portfolios. The organization, content, and accessibility of information could be directly evaluated by asking questions that tested directly a student's ability to retrieve information from his or her portfolio. This method of evaluation is much less time-intensive than the spot-checking method used previously; in addition, professors have increased confidence that the earned scores reflect the quality of the portfolio. Student portfolios were observed to improve between the time of the midterm and final evaluations.

Overall, the three professors using clickers in Freshman Clinic I at Rowan University in Fall 2007 had favorable experiences. Each plans to continue to use clickers.

A survey of five professors using clickers in seven separate classes (including courses other than Freshman Clinic I) found that the professors were unanimous in strong agreement that the clickers increased student engagement with the class material, and the faculty members' overall impression was that the students enjoyed using the clickers in class.

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