

## Using Clickers in Calculus

Fei Xue<sup>1</sup>, Jean McGivney-Burelle<sup>2</sup>

Department of Mathematics, University of Hartford,  
200 Bloomfield Ave. West Hartford, CT 06117, USA.  
xue@hartford.edu

**Abstract:** In this paper we provide an overview of our experience using clickers in Calculus. Clickers are student response systems which collect students' voting results on a question posted by the instructor and displays statistical results instantly. We briefly discuss the different types of clicker technology available and our experience using clickers. In addition, we present the benefits of using clickers and classroom voting in Calculus and discuss different types of clicker questions we have posed in our classes. This new technology and teaching method can be easily applied in other science, technology, and engineering courses.

**Keywords:** Clicker, Calculus, classroom voting, student response system

### 1. Introduction to Clickers

Student responses systems, also referred to as “clickers”, are increasingly being used in mathematics classrooms to engage students in learning and to provide more frequent feedback to students and instructors about student understanding. Instructors who use clickers design their instruction around multiple-choice, true-false, and, to a lesser extent, numerical response questions. These questions are posed to the class, often through presentation software such as PowerPoint, and students spend a few minutes reflecting on the question and discussing the answer in small groups. Each student can register his/her answer by typing a response on the clicker (see Figure 1 below). The clicker software instantly collects students' answers via a USB receiver and displays the statistical result through the presentation software (see Figure 2).



Figure 1. Clicker (RespondCard NXT)

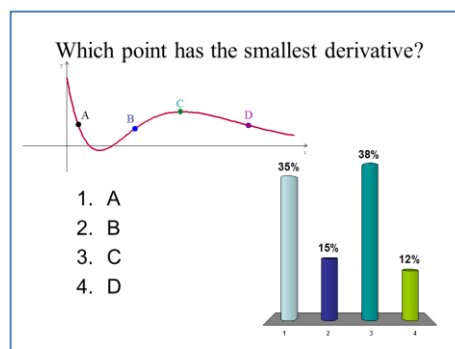


Figure 2. Results of voting question shown in PowerPoint

Compared to a traditional lecture where there is little student participation, classroom voting via clickers gives every student a chance to answer questions asked by the instructor. There have been numerous studies discussing the benefits of using classroom voting in teaching mathematics (Bode, Drane, Kolikant & Schuller 2009; Bressoud 2009; Cline 2006; Cline, Zullo, & Parker 2007; Cline, Zullo & VonEpps 2012). In particular, these studies have shown that classroom voting fosters more student engagement and contributes to improved learning.

Early generation clickers limited instructors to posing multiple-choice or true-false questions. The latest version of RespondCard NXT clickers has a LCD screen which accepts numerical answers (e.g., students can type in 2.314 for an answer) and response to short answer questions (e.g. students put in  $\sin(x)$  for the answer). The benefit of the relatively large LCD screen is that students can review their answers before submitting.

## 2. Clicker Technology

Integrating classroom voting and clicker technology into the classroom is a relatively easy endeavor. In addition to the ResondCard NXT and its earlier versions made by Turning Technology®, there are other student response systems available (e.g., SMART Response™ PE). These systems require that each student has his/her own clicker therefore the initial cost, either to the student or the instructor, is high. The benefit of using this style of clicker is that students do not need to prepare or install anything, and it is very easy to use. The instructor software is free and can be added on to PowerPoint or PDF.

A different type of student response system is based on cell phone text messaging. For example, Polleverywhere® allows students to vote via text messages or vote online using a smartphone. In this case there are no expenses for purchasing the “clicker” assuming that each student has access to a cell phone. However there is a monthly or annual charge if the class size is over 40. In addition, if students use text messaging to submit answers they may have to pay a text message fee.

Some newer classroom voting systems are internet-based. For example, the iResponse® is an application that can be used on iPad, iPhone or iPod touch. It receives the voting information via wireless internet or a stand-alone router. It will be ideal if the class has already used iPad in teaching. eClicker Client® is a similar product but requires wireless signal in class. Clearly, this type of technology would make answering short-answer questions that much easier and will create a need for writing more good questions that allow students to submit these types of answers.

## 3. Our Experience with Clickers

The University of Hartford is a mid-size private university located in the northeastern United States. There are approximately 8 sections of Calculus I offered every fall and 6 sections of calculus II every spring. The average class size is approximately 30 students. In the 2011-2012 academic year, we began using clickers in our Calculus I and Calculus II classes. To implement classroom voting we took our existing PowerPoint notes and inserted 3 or more voting questions in every lecture towards the middle and end of each class. All of our students were assigned their own clicker and would pick up their assigned clicker from a table in the front of the room at the start of every class. While some instructors collect individual student data with the clickers we decided to allow our students to respond to questions anonymously. Since the main purpose of our classroom voting questions was to assess whether the majority of the students had understood the material we were teaching rather than tracking individual student performance. This approach worked well for us. In general, we would wait for at least 80% of the students to respond before we showed the results of each vote. If most of the students picked the correct answer, we would move on to the next topic or problem. Otherwise, we would present additional problems or questions. In some cases we posed more challenging questions that attempted to uncover students' misconceptions about the mathematics. These questions often lead to more interesting discussions and, it is hoped, a deeper understanding of the content.

## 4. Benefits of Using Clickers

We noticed several benefits of using clickers and classroom voting in our mathematics courses and many of these advantages are aligned with principles for good practices in undergraduate education (Chickering & Gamson, 1987) including they:

*Increase faculty-student interaction.* Before adopting clickers in the classroom most of our students were quiet in class. When students worked on the clicker questions there was much more discussion and we, the instructors, had more opportunity to work with individual or small groups of students who had questions about the mathematics.

*Foster student cooperation and collaboration.* After we posed each clicker question students were encouraged to discuss the question with their peers and try to come to some consensus on the correct answer. Students had the

opportunity to explain their mathematical thinking, support and defend their arguments, and challenge each other's thinking.

*Promote active learning.* Since every student has a clicker, every student can become actively involved in answering questions and contributing to class discussions.

*Improve student engagement.* By posing clicker questions every 10-15 minutes in a class presentation, we catch students' attention and help break up a long class into several smaller blocks of time.

*Provide prompt feedback.* Since responses to clicker questions are displayed instantaneously the instructor gets feedback on whether students are understanding the material or not. By having access to this information in real time instructors can use this information to re-teach parts of the lesson or move on. Further, students appreciate knowing whether they are making sense of the mathematics without having to wait until the next quiz or test.

We gave an end-of-semester survey to the students about using clickers (N=56). Students were asked to rate their responses on a scale of 1 (strongly disagree) to 5 (strongly agree). In general, students seemed to enjoy and benefit from using clickers in the classroom. The survey results are shown in Table 1 below.

Table 1. Student attitudes survey about using Clickers

Questions	Score
The clickers help me learn mathematics better.	4.17
I am more engaged in learning with clickers.	4.23
Clicker questions are better than traditional worksheet questions.	4.15
Overall, I like clickers.	4.28
I would like to have more clicker questions in class.	2.79

The survey also showed that there should be approximately 3-5 clicker questions per class. Too many clicker questions could result in running out of class time. In lower level classes that aren't prerequisites for other courses (e.g., Mathematics for Liberal Arts) there is likely the opportunity to pose and discuss more questions.

## 5. Different Question Types

Many faculty members who use classroom voting are attempting to develop "good questions" (Lomen & Robinson 2004; Mille, Santana-Vega, & Terrell 2006; Pilzer 2001). Often times these good questions have voting results which are either spread across all possible answers—that is, where no answer received a majority of the votes—or where the majority of students vote on the wrong answer. Good questions provoke rich discussions and allow students to arrive at a better understanding of key concepts. [Note: Over 2000 multiple choice or true-false classroom voting questions for many college level mathematics courses including Calculus, Linear Algebra, Differential Equations and Statistics can be found at <http://mathquest.carroll.edu/>]

An example of a good question from our Calculus I class is shown here.

If $f(x) = e^7$ , what is $f'(x)$ ?			
(a) $7e^6$	(b) $e^7$	(c) $e^7 \ln 7$	(d) 0

Students who are in the midst of learning the many rules of derivatives can easily get confused by this question. In discussing the answer to this question, students can arrive at a deeper understanding of exponential functions, power functions and constants and the rules for finding the derivative of each type of function.

Often times in the middle of class we pose clicker questions to assess whether students have mastered a new formula. Sometimes it is more ideal to ask questions where students can enter numerical responses rather than multiple choice answers. For example, suppose we want to pose a question to remind students that the derivative of  $f(x) = \cos(x)$  is  $-\sin(x)$ . If we use a multiple choices question, students may get the hint by the choices. In this case, we could change

the problem to a numerical problem, e.g. find  $f'(\pi/2)$  and let students directly enter in the number rather than selecting one of several choices. One advantage of posing a numerical question is that instructors do not need to worry writing good or distracting answers, which is an important and time-consuming part of designing good multiple-choice questions. By allowing students to enter numerical answers we also can get a better sense of some common incorrect answers that we could use in future efforts at writing good multiple-choice questions.

Our clickers also support short-answer questions however this feature hasn't turned out to be as useful in our mathematics courses. The input is similar to older-style cell phone (non-smartphone) text messaging and therefore requires a lot of typing. Even a very short expression can take a long time for students to input and it is very easy to have typos. As a result we have abandoned using short-answer questions until the technology improves.

## 6. Summary

In our limited experience, classroom voting and clickers have proven to be effective pedagogical tools for engaging students in Calculus. Students enjoyed using the clickers primarily because they liked knowing whether their answers were correct or incorrect, they appreciated being able to talk to classmates about the answers to clicker questions, and they thought it was more fun to use the clickers rather than raise their hands to answer questions. As instructors we found the technology to be very easy to use and appreciated the frequent and immediate feedback we received about students' understanding of the course content. We believe clickers can also be easily adopted in other science, technology, and engineering courses. The most important part is to find or write appropriate voting questions.

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