Teaching with Classroom Voting

By Kelly Cline, Holly Zullo, and Mark Parker

Classroom voting is a new and useful teaching technique in mathematics. The instructor poses a multiple choice or true/false question to the class, waits for a brief period of consideration and discussion, then has the students vote on the answer, either by holding up colored index cards (a = red, b = blue, etc.) or using a computerized personal response system, where each student registers a vote with a hand-held "clicker." After the vote, the instructor guides a Socratic discussion, asking several students to explain their thinking. The instructor gets immediate feedback on the state of the students' understanding. The voting gets the students to actively engage in the class, to discuss the issues with their peers and to express an opinion. Students confront common misconceptions before doing the homework.

Student reaction to this teaching technique is generally quite positive: They enjoy playing an active role in the classroom, they have fun clicking in with their votes, and often attendance improves.

A growing body of research demonstrates that not all questions and not all methods of using classroom voting are equally effective at promoting student learning. A recent study at Cornell (http://www.math.cornell.edu/~maria/mathfest_education/preprint.pdf) showed that when instructors chose to focus on questions that probed conceptual issues and used these questions to motivate student discussions before each vote, there was a significant improvement in student learning, as demonstrated by an analysis of scores on common exams.

What makes a really good voting question?

How can a multiple-choice question probe important underlying issues? A carefully crafted question really can get at the deeper concepts. For example, suppose you're teaching first-order differential equations and have introduced the idea of equilibrium. You could pose this question:

The amount of a drug in the bloodstream follows the differential equation $c' = -kc + d$*, where d is the rate at which it is being added intravenously and* k *is the fractional rate at which it breaks down. If the initial concentration is given by a value* $c(0) > d/k$*, then what will happen?*

a) *This equation predicts that the concentration of the drug will be negative, which is impossible.*
b) *The concentration of the drug will decrease until there is none left.*
c) *This means that the concentration of the drug will get smaller, until it reaches the level* $c = d/k$*, where it will stay.*
d) *This concentration of the drug will approach but never reach the level d/k.*
e) *Because* $c(0) > d/k$ *this means that the concentration of the drug will increase, so the dose d should be reduced.*

In a recent class, our students were divided fairly evenly between c and d, with a few voting for other answers. The discussions both before and after the vote were very rich, with the students actively trying to decide whether the level of the drug would actually reach equilibrium. In the post-vote discussion, they came to understand that d was correct, and that the level of the drug would asymptotically approach, but never quite reach equilibrium.

Questions posed with a context and in natural language are particularly good at provoking discussion, in particular because students have to translate the mathematical ideas into ordinary speech. Rather than asking students what happens "in the limit as t approaches infinity," ask them what happens "in the long run" and then watch them grapple with the meaning of the mathematical ideas.

How do you make it work?

Classroom voting is a fun technique that can really change your classroom in positive ways, but how do you make it work? One easy way to get started is to hand out a numbered list of questions to the students at the beginning of the course or unit. That way, the instructor simply calls out a question number to get each vote going. We've found that before the first vote takes place, it's important to explain to the students what's going on and why. Emphasize that the main purpose of classroom voting is to get them to discuss the mathematics in small groups before each vote. To promote this, it is generally useful to give the students plenty of time to work things out, up to four minutes if necessary, and only close the voting when most students have registered in, or if the relevant discussion peters out.

After the vote, it is important to guide a Socratic discussion, calling on different people and asking them what they voted for and why. Sometimes students will try to avoid the issue, saying that they just guessed and they don't know. At this point, it helps to emphasize that it doesn't matter whether you are right or wrong, as long as you have something to say, some idea, some insight to offer. "If you don't have any ideas, ask the people around you, and if they don't have any, it's okay to get up and ask around until you learn something."

In the post vote discussion, don't give away the correct answer too quickly: Be coy! Call on a variety of students and try to let them figure it out themselves. Often when the right explanation comes out, the answer is clear and you'll hear students say "ah!" around the room.

Who has the time?

Classroom voting takes time, roughly one to four minutes for the pre-vote discussions, and usually a similar amount of time for discussion afterward. This means that a few votes can easily eat up half of a class period, so who has time for voting? The key to using classroom voting without slowing your pace is to use the voting to teach many of the ideas that would otherwise be taught via lecture.

Instead of doing several examples on the board, try doing one, and then use voting to get the students to work through the others themselves. Just give the students the bare essentials in a short lecture segment, and then let them figure out the rest. You might be surprised at how well your students can connect the dots when they are working together to figure out a voting question.

Use questions to provoke common misconceptions and pitfalls, or special cases when the usual techniques don't work, and then after the vote they'll be ready to listen when you explain the way out. In calculus, ask the students to work out the antiderivative of $1/x$ and watch them notice how the power rule fails.

We've been using classroom voting in our calculus classes for the past several years, covering exactly the same syllabus and giving the same types of exams as we did before. Rather than viewing classroom voting as an add-on to be crammed in at the end of the class period, we let the voting replace about half of each lecture and intersperse the questions throughout the period. The same concepts are taught but in a more student-centered way.

Where do you get the questions?

Writing multiple-choice questions that push students' understanding of the concepts behind the mathematics isn't easy. Some publishers are now offering collections of voting questions, sometimes called *ConcepTests*, to supplement their texts. If these exist for a text you use, that can be useful; however sometimes these questions focus on straight-forward computations and more basic applications of the main ideas — not the deeper issues that have the greatest educational impact. Just holding votes isn't enough!

The research shows that high quality conceptual questions are the ones that make a real impact. Fortunately there are some good sources out there: The NSF funded *GoodQuestions* project at Cornell, at http://www.math.cornell.edu/~GoodQuestions/, has developed and tested a library of classroom voting questions that are specifically designed to get students to grapple with the key ideas of calculus.

More recently, the NSF has funded our *Project Math QUEST: Math Questions to Engage Students* (see http://mathquest.carroll.edu/), and we are writing and testing a library of questions to use in differential equations and linear algebra courses. We have working drafts of these questions up and are looking for collaborators at other institutions who would be willing to try out some of them. If you'd like to get involved, please visit our website and take a look.

Give classroom voting a try!

Classroom voting is a powerful new teaching method that engages students, getting them to actively participate in the classroom. It takes a little preparation, but the results are well worth the effort. To get the most out of this technique, first use the best questions that really push the students' understanding of the key mathematical ideas. Second use the voting to replace parts of your lecture, allowing the questions to draw out the ideas that you would otherwise have to present. Third emphasize that the pre-vote discussions are the real engine of this process: When your students are debating and discussing the mathematical ideas with their peers, then real learning is taking place.

Kelly Cline, Holly Zullo, and Mark Parker teach at Carroll College in Helena, Montana and have received an NSF grant for Project MathQUEST, to develop and test classroom voting question for linear algebra and differential equations.

Math Doesn't Suck

Danica McKellar, the young actress who appeared in *The Wonder Years* and who graced the cover of *Math Horizons* in April, 2001, has written a book intended to get "tween" girls excited about mathematics. (For those not up on this particular bit of modern jargon, "tweens" are children between 8 and 12 years old, who are not little kids any more but not yet teenagers.) Entitled *Math Doesn't Suck*, the book will be released in early August. The promotional material describes the book: "Danica uses situations from real life not only to illustrate how useful math can be, but also to give girls little "tricks" to help them grasp some of math's tougher concepts. Topics range from buying lipstick (factoring) to making beaded bracelets (prime numbers) to trying to figure out if you're really over your last crush (greatest common factors). It's an engaging way to show girls that exercising their brains will give them a power that no amount of physical beauty can match." MAA Reviews has been promised a review copy.