USING CLICKERS TO ENCOURAGE COMMUNICATION AND SELF-REFLECTION IN MATHEMATICS

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Introduction

Over the past decade, classroom response systems have been used to promote more active learning in collegiate classes, particularly in large lecture formats (Mazur) [1]. These student polling systems can be used to gain an understanding of students' knowledge of a specific concept. The polling results, including votes for each of the potential optional answers to a question, can be displayed to the class after all students have an opportunity to vote.

Personal response systems include an instructor receiver unit, Figure 1, that collects the votes sent by all students. Software for displaying and storing the polling is required, and in the case of the i-clicker system is incorporated on a provided flash stick that plugs directly into the teacher receiver. The radio frequency instructor receiver unit is plugged into any USB port on a computer. The i-clicker system integrates with either of the Macintosh or PC platforms.

In addition, a set of handheld devices, clickers, provides the means for each student to enter his or her vote and send it to the receiver unit. Figure 2 shows an example student handheld device that we are using in our classes.

Figure 1 Instructor Receiver Station

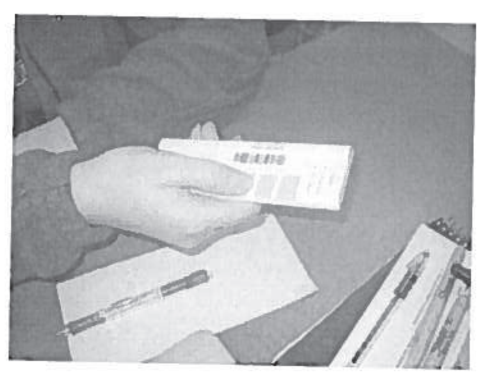

Figure 2 Student Polling Handheld Unit

There are a wide variety of systems available. Our campus has adopted the i-clicker system due to the ease of use on any platform and the fact that this system resides on the desktop. It acts as a floating toolbar on the desktop so that it may be utilized with the instructor's choice of software. An important decision to consider with such an adoption is the type of input and number of inputs students may enter. With this system, students must select one of at most five options to a question, and inputs are just a click of one of five buttons. This system does not have calculator functionality nor numeric inputs.

Evolution of Use

This paper describes our experiences over the last three semesters using i-clickers in our respective collegiate mathematics courses: liberal arts math, math for elementary teachers, pre calculus, business calculus and statistics. Since our initial implementation of clickers in our classes, our uses have evolved into what we believe are optimal uses of the personal response systems to enhance our students' understanding, as well as our own understanding of our student's thoughts about the material. Our evolution of use of polling over this time period moved from occasional single item use to almost daily use of related deepening questions.

In our first semester of use, we often adapted released clicker items for pre calculus, business calculus and statistics courses using online databases of such items (Zullo, Kline) [2] (Murphy et. al.) [3] and texts such as the Connally et. al. *Functions Modeling Change: A Preparation for Calculus* [4] which included conceptual clicker items with their materials. Usually clicker items were utilized in these courses and were spaced so that an item would be used to start the class discussion. Frequently, this was followed by another clicker item with more discussion midway through the class, and an item near the end of the class time.

For the liberal arts math course and the math for elementary teachers courses, there were no databases of clicker items currently available, so this provided the impetus for us to develop one or two key conceptual questions for each class period based on our combined forty years of teaching experience. Our experience interacting with students and assessing their work provided alternative response options based on commonly held misconceptions. Conceptually based questions were infused into the classroom sessions usually at the beginning of the class. The focus of these conceptual questions was not just to select the appropriate answer, but also to focus on why students may have voted for one of the other options. What might be the idea that is confusing to the student? This type of questioning and discussion is helpful in each of our classes, and is especially helpful for our future teachers as they prepare to address similar misconceptions in their future teaching.

Since this first semester of incorporating student voting into mathematics classes, we have found that we use classroom voting as part of the organizational structure of the class. Our pre-class notes for the math for elementary teachers courses now includes all planned clicker items, examples and non-examples or counter examples supported by these items, as well as definitions, representations, models and homework. The discussion of the "clicker item at the start of the day", used the first semester, has been replaced by a well-organized series of related items to encourage in-depth discussion, multiple viewpoints and self-reflection.

Models of Use

Although clicker items could be used as "just-in-time" teaching activities to gain an understanding of whether or not the class has followed an instructor's lesson, we have chosen to focus our use of classroom polling in different ways.

We use a variety of different modes of clicker use. One model we often use is to ask students to first answer a presented question, by themselves, then discuss the question with their small group members, then come back and revote on the question. We often mix it up on whether or not we show the class the results in between voting, or if we wait to show how things changed after the classroom discussion ensues.

One of the goals of our use of personal response systems is to encourage discussion and communication among students in our courses. A shared vision of standards based documents produced by the Mathematical Association of America (2004) [5] and the National Council of Teachers of Mathematics (2000) [6] is to create learning environments where students are discussing and solving challenging and motivating mathematical problems.

Collegiate mathematics is traditionally thought of as a passive learning, lecture course rather than an active discussion course. We find that we are able to motivate more discussion among our students by using clicker items. The discussion begins as they explain why an answer to a selected question is correct. We select questions that focus on conceptual ideas rather than on skill practice. Often our items are ones which could be modified by making parameter changes within the model of the application presented. We ask our students to debate the solution choices in their group and that they should either, "A: convince someone else in your group that your answer is correct or B: you will be convinced by someone else in the group that their answer is correct" (Hofacker, et. al.) [7]. We emphasize the reasoning behind the solution option. This mathematical reasoning is more important than simply voting for the correct answer.

Sometimes a clicker item will provide discussion of the additional mathematical information required to select an option. For example, the discussion of the options presented in the item in Figure 3 [4] [7], provides a focus on domain specificity.

For how many angles of x, does $\cos x = \sin x$?

a) 1
b) 2
c) 3
d) 4
e) 5

Figure 3 Trigonometry Example Item

In the past, we have avoided the use of multiple-choice questions on assessments, in order to focus on student work including representations and explanations. It is interesting that the clicker questions are multiple-choice items and that it is the set of options that are used to generate discussion and mathematical reasoning about alternatives. It is this first step of interaction which requires all students to think about a mathematical question and invest in an option by voting for it, that has changed our view about the usefulness of multiple-choice questions in teaching. Once students have engaged in the problem by voting and thinking about it, they are encouraged to communicate about mathematics in ways they may not ordinarily have done in the past.

Using the multiple-choice format, the instructor can also imbed common error patterns, incorrect yet intuitive options, or misconceptions into an item. The experience encountered by students learning that they have voted for an incorrect response and why it is incorrect, is often cited as an opportunity for reflection and learning that is individualized. This process appears to help students understand what they do not know, which may not occur to them if they sat passively in the class only observing problems solved by the teacher or other students.

We have begun to see an increase in the involvement of greater numbers of students in the discussion that takes place in our classes, whether we are currently using a clicker item for motivation or not. Students become enthusiastic about sharing explanations, representations, and questions. The classroom environment must support an inclusive atmosphere to encourage this increased participation to take place, where students feel safe about sharing their thoughts [7].

Another goal of our use of clickers is to ask students to expand on their ability to represent mathematical situations and to discuss alternative representations. For example, after the study of simple probability experiments, such as single coin tosses, we posed a question to lead to a discussion of complex experiments with multiple artifacts (Figure 4).

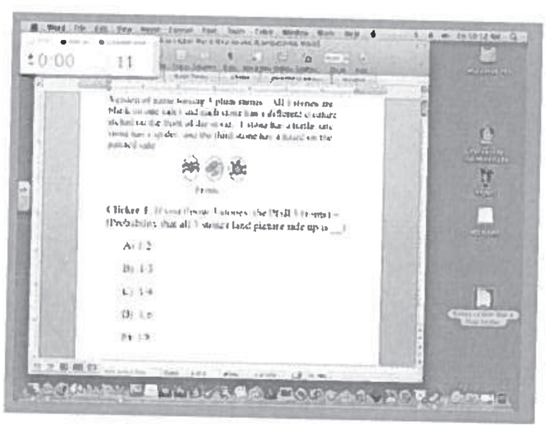

Figure 4 Three 2-sided Stones Item

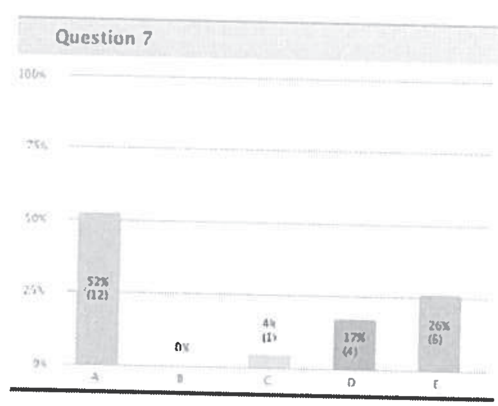

Figure 5 Student Initial Votes

The problem posed is analogous to that of tossing three fair coins and asking for the probability that all three two-sided fair coins, stones in this case, will land on heads, i. e. picture side up. This first exposure to multiple random artifacts used in a single toss resulted in four different option responses. The majority of the students voted incorrectly for the result one-half instead of the result of one-eighth (Figure 5). As part of the analysis and discussion, students drew diagrams and explained their reasoning for their choices. Surprisingly, the result of one-half was not selected simply because each coin had a 50-50 chance of landing with the picture side up, but instead on their drawings, overwhelmingly, students drew 6 sides of the stones where 3 had pictures diagrammed on them and 3 were blank. These representations were showing 3 of the 6 sides or one-half as landing picture side up. An exciting discussion of representations and sample space for this question ensued.

Conclusion

As we finish our third semester of using classroom response systems in our mathematics classes, we have found many positive effects for our teaching and student learning.

Our students are engaged in problem solving. Reluctant learners are involved that may normally have been concerned about sharing incorrect ideas in class. All students have an anonymous voice and invest in their learning by voting. Instant results of the classroom voting are available, see Figure 5 for an example screen shot of a voting display as seen on a Mac. Voting on key conceptual items starts the mathematical conversation and encourages all students to share their reasoning first in small groups and then with the full class. Active participation starts with a single vote and progresses to discussion, debate, modeling and representations. Students become more aware of common misconceptions and how to use reasoning and representations to address these.

Uploading the conceptual items, examples, and representations daily to a classroom management system provides students with additional resources for learning and study. As instructors, incorporating personal response systems has focused our attention even more than before on common misconceptions and how questioning, representations, and reasoning through class discussions can help promote understanding in mathematics.

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