Using Clickers in Physics Lectures with Predominant Minority Students

Pengfei Li [a)], Jonathan Lambright [b)]

Department of Engineering Technology and Mathematics, Savannah State University, Savannah, GA, 31404

(Received 5 January 2012; accepted 29 February 2012)

At Savannah State University (SSU), a Historical Black College and University (HBCU), an in-class response system (clicker) was used in an algebra-based physics introductory course to answer multiple-choice questions during lectures. Two types of clicker questions sequences were used to improve students' interaction in class and help students understand physics concepts: "rapid fire" sequences and "easy-hard-hard". Attitude survey showed students liked using clickers and felt more engaged in lectures after using them. Voting results showed two different patterns for "rapid fire" series and "easy-hard-hard" series. These results were also compared with voting results by students from the Ohio State University (OSU).

I. INTRODUCTION

It has long been understood that traditional forms of lecture instruction are not optimal for teaching concepts (Peters 1982). Lectures are cost effective but not learning efficient, so educators continue to search for methods that enhance student participation in this traditionally passive environment (Crouch 2001; Price 1997). Clicker is a generic name for in-class polling systems used by students to answer multiple-choice questions during lectures (Dufresne 1996). These devices started getting popular in the past five years and have been used on hundreds of college campuses.

It has been demonstrated in many universities that the use of clickers improve classroom dynamics, in particular, student-lecturer interactivity. Draper et al. showed that the most promising pedagogical approaches of using clickers appeared to be Interactive Engagement (Draper 2004). Reay et al. reported that students liked using clicker and thought using clicker helped them understand the questions better (Reay 2005). Reay et al. also found that students using clickers performed both better on common conceptual survey question and regular exam questions (Reay 2008).

In the past decade, major efforts have been made by the federal government and educators to increase the population of minority students in higher education, especially in Science Technology Engineering and Mathematics (STEM) related areas (Pender 2010; Vasti 2010). Most of the research on how to use clickers were conducted at universities with mainly white students; little research has been conducted on how clickers has been used in a classroom with mainly minority students. At Savannah State University, a Historical Black College and University (HBCU), clickers were used in an algebra-based physics introductory course. The purpose of this paper is to report results from implementing clicker method in a new environment and compare such results with results from students also in an algebra-based physics introductory course at Ohio State University (mainly white students).

A. Question Methodology

As reliable and inexpensive clicker systems have become commercially available, the present challenge is to create questions that are optimal for improving students' understanding of physics. Clickers generally have been used in a one question per concept format with a single set of surface features. A new methodology has been created at the OSU PER group, which emphasized the use of a sequence of questions, each displaying the same concept in a different context (Reay 2005).This methodology was based on a constructivism paradigm widely used in active engagement curricula developed in physics education research, but applied that paradigm within a much shorter time frame during lectures. The design of each question was based on specific difficulties that students reveal during learning. These question sequences can be divided into "rapid fire" series and "easy-hard-hard" series (Reay 2008). "Rapid fire" question sequences usually contain questions that are of modest difficulty, so students can gradually build their knowledge structures. An example of a rapid-fire question sequence is shown in Figures 1, 2 and 3. This sequence was developed to give students practice in using the right-hand rule for forces on charged particles moving in a magnetic field.

These three questions were presented together in this paper, but were shown to students in a separate slide for each question. This question sequence was given right after students had heard the right hand rule discussed and was the first time that they actually practiced it by themselves. Students were given 40 seconds to answer each question, and the discussion that followed was brief. In the first question, only 37% of students selected the correct answer (A). In the second question, 52% of students chose the correct answer (C). Finally, 79% of students picked the right answer (D) in the third question.

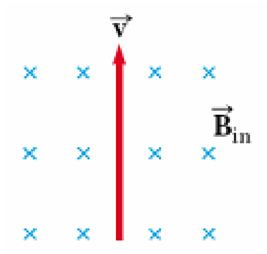

Figure 1.

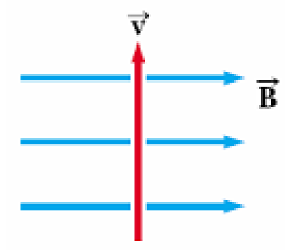

Figure 2.

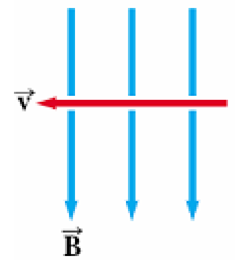

Figure 3.

Right hand rule question sequences: A positive charge is moving in the magnetic field. Which way is the magnetic force pointing to?
A) Left B) Right C) In D) Out E) Up F) Down

The monotonically increasing percentage of correct answers is a characteristic pattern for rapid-fire question sequences, whose goal is to have students improve by practicing skills with slightly changing context variables.

B. "Easy-hard-hard" question sequences

An "easy-hard-hard" question sequence is a three-question sequence in which all three questions focus on the same concept, but have different features. The questions appear similar to experts, but appear different to beginning students who are often attracted to surface features of the context.

The first question is easy. The role of the first question is to review some basic concept and make students comfortable answering questions. The second question is usually hard, and only a fraction of students get the right answer. The purpose of this question is to create an impasse and help students realize that they do not yet fully grasp the concept. The third question, which has the same concept as the other questions but different context features, is also hard. This question is used to check whether students fully understand the concept or not. An example of the "easy-hard-hard" question sequence is shown in Figures 4, 5, and 6.

In the first question (Figure 4), the bare wire shorts out two of the resistors, so the correct answer is V/R. The fact that 57% of the students chose the right answer indicated that more than half of the students understood the concept "short."

In the second question (Figure 5), all three resistors are in parallel, and the correct answer is 3V/R. Only 9% of the students chose the right answer. 56% of the students actually chose answer V/R. This indicated that the students had trouble redrawing the circuit, and may have made an educated guess. The lecturer then traced the wires, under the direction of the students, to determine how each particular resistor was connected in the circuit.

The third question (Figure 6) at first seems different than the first two. However, the resistor on the right-hand side is shorted out as occurred in the first question, and the other three resistors are in parallel as in the second question. The correct answer is again 3V/R. This time, 43% of the students voted for the correct answer, which indicated that students benefited from the discussion of question 2, but many students still may have had difficulty tracing wires as 24% of the students choose answer 2V/R. After discussing with each other, 69% of the students chose the right answer during the revote. 17% of the students chose 2V/R, which indicated that some students still had difficulty tracing wires.

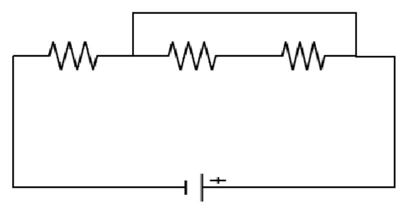

Figure 4. DC circuit question 1: In the following figure all resistors have the same value R and the voltage of the battery is V. Find the total current flow through the battery. One way to do this is to trace each possible path from one side of the battery back to the other side.

A) V/R B) V/2R C) V/3R D) 2V/R E) 3V/R

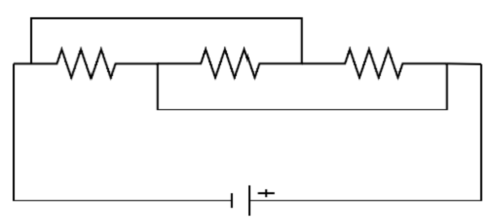

Figure 5. DC circuit question 2: Now, you add one wire to the same circuit as shown. Though there is only one additional wire, there are more paths going from one side of the battery to the other. Find the total current flow through the battery at this time. A similar question was used at a high school Science Olympiad.

A) V/R B) V/2R C) V/3R D) 2V/R E) 3V/R

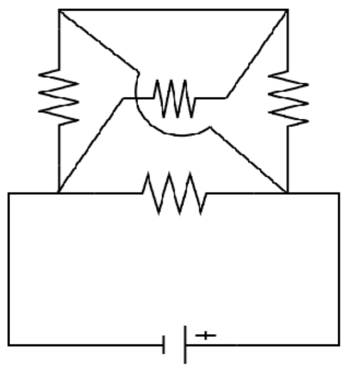

Figure 6. DC circuit question 3: Consider the circuit given below. Again, each resistor has the same value R and the battery's voltage is V. Find the total current flow through the battery. *The loop in the diagonal wire means that it loops over the other wire and is connected only on its ends.* This is similar to another Science Olympiad question which had a 5th resistor in place of the wire across the top.

A) V/R B) V/2R C) V/3R D) 2V/R E) 3V/R

II. RESEARCH DESIGN

The primary research question was whether using clickers with the same new methodology in a class with predominantly minority students (SSU) can improve students' understanding of concepts the same way as in OSU, and whether the effectiveness of using clickers to help students learn concepts depends on the backgrounds of students. Answering this question was accomplished by comparing the voting results between the same levels of students from the two universities.

A secondary goal of our study was to answer affective questions such as whether students at SSU enjoyed using clickers, and whether they perceived that using voting machines helped them learn. Affective and motivational factors are important aspects of learning because in order to succeed in one area, students must have interests and enthusiasm in that area. Students' self-reporting of preferences and attitudes has been used for decades as supplemental information while evaluating education innovations. This goal was achieved by the end-of semester surveys.

Clickers were used in the spring 2009 term of a two-semester algebra-based introductory physics course at SSU. The main topic of this course is electricity and magnetism. The class size is 35. Among them, 31 are African American students. Students picked up and returned the handheld units before and after each lecture, and the units were periodically checked by the instructor to ensure technical integrity. Students were not assigned with dedicated handheld units so the instructor could not trace individual votes. More than 95% students attending lectures voted even without any credits given.

III. RESULTS OF STUDENT VOTING PATTENS

Comparing voting results between students from two universities is one way to demonstrate if using clickers in a class with predominantly minority students (SSU) can improve students' understanding of concepts the same way as in OSU. A previous study showed that students with different performance in class may benefit differently from different types of questions (Li 2007). Comparing students' voting results between two universities may help instructor at HBCU design their own question based on the students' backgrounds.

Because "rapid fire" sequences and "easy-hard-hard" sequences have different features and difficulties, they seem to have resulted in different student voting result patterns. Students with different backgrounds seem to learn differently from them. The voting results for "rapid fire" sequences usually increase gradually and eventually reach a high percentage. The voting results for "easy-hard-hard" sequences, on the other hand, typically start with a high percentage on the first question, follow with a low percentage on the second question, and finally end up with a medium or high percentage on the third question. Students' voting patterns from two universities on two different types of questions are shown below.

A. Student voting patterns on "rapid fire" sequences

Because the number of questions in a "rapid fire" sequences is usually different (the number usually varies from 3 to 6), in order to compare the voting results between different question sequences, the average from the 2nd question to the second last question was used as the voting result of the "second question." For example, if a question sequence has N questions, we used the average from the second question to the N-1th question as the results of the new "second question." The voting results of all 16 "rapid fire" sequences used in our study were averaged and shown in Table 1. These results were also compared with results by OSU students.

Table 1. Voting result pattern on "rapid fire" sequences

	First questions	Second questions	Last questions	#of students who voted
OSU Average	39%	68%	86%	186
SSU Average	31%	57%	71%	30

As data shown in Table 1, the voting result pattern on "rapid fire" sequences by SSU students was similar with the voting result pattern by OSU students. Students in both institutions started with low percentage of right answers and gradually reached high percentage. The average scores from SSU students were consistently lower than the scores from OSU students.

B. Student voting patterns on "easy-hard-hard" sequences

The averages of all three questions in all 7 "easy-hard-hard" sequences used in our study are shown in Table 2. These results were also compared with results by OSU students on the same "easy-hard-hard" sequences.

Table 2. Voting result pattern on "easy-hard-hard" sequences

	First questions	Second questions	Last questions	#of students who voted
OSU Average	72%	27%	67%	180
SSU Average	55%	23%	46%	28

As data shown in Table 2, on the first questions of "easy-hard-hard" sequences, the voting scores by SSU students was 17% lower than scores form OSU students. On the second questions, students from both universities scored approximately 25%, though students from OSU still scored slightly higher than SSU students. This was also consistent with the desired results of "easy-hard-hard" sequences. On average, 67% of the students at OSU chose the correct answer, while only 46% at SSU chose the right answer on the third questions, students from OSU scored 21% higher than students from SSU. Based on the scores, it seemed that students from SSU benefited less from "easy-hard-hard" sequences than students from OSU.

There could be two possible reasons. First, students in these two classes have different backgrounds. The average SAT scores for OSU student is 1820, while the average SAT scores for SSU students is 1280. Research showed that lower achieving students benefited less from "easy-hard-hard" sequences than higher achieving students. Second, clickers were used by different instructors at OSU and SSU. The instructor who taught at OSU has more than thirty years of teaching experience, while the instructor at SSU has only less than five years of teaching experience.

IV. RESULTS OF STUDENT SURVEYS

Students' self-reporting of preferences and attitudes has been used for many years as supplemental information for evaluating education innovations (Armarego 2007). In this study, students were given an end-of-quarter attitude survey soliciting their views about using clickers. Survey questions were answered using a 5-point scale ranging from 1 (totally disagree) to 5 (totally agree). Each type of preference or attitude included several similar questions worded differently and sometimes in both positive and negative tones. The survey results were compared with survey results from students at Ohio State University (See Table 3).

These results showed that students' self-reporting of preferences and attitudes for clickers did not depend on their backgrounds. Students in both institutions liked using clickers and thought that using clicker helped them understand the questions better.

Table 3. Clicker Attitude Survey results for OSU students and SSU students

	I like using clickers	Clickers helped me understand lectures better.	Clickers made me feel involved in the course.	Clickers helped me get instant feedback on what I knew and didn't know.	I would recommend using clickers in all future introductory physics courses.	Using clickers is a waste of time.	I will avoid classes using clickers in the future.
OSU Average	4.69	4.38	4.51	4.66	4.60	1.58	1.46
SSU Average	4.67	4.41	4.38	4.46	4.53	1.69	1.87

V. CONCLUSIONS

Voting results of SSU students on "rapid fire" sequences were mostly consistent with the results from OSU students. Students in both institutions seemed to benefit from "rapid fire" sequences where the voting results started from low percentage and gradually reached high percentage, although OSU students scored around 11% higher than SSU students consistently, while there was a difference between the voting scores of OSU students and SSU students on the "easy-hard-hard" sequences. Students from both universities scored around the same on the second questions, while student from SSU scored considerably lower on the third questions, which may suggest that the "easy-hard-hard" sequences may not benefit SSU students as great as the “rapid fire” sequences due to SSU students' weaker background. SSU students seemed to benefit more from gradually building their knowledge structures (“rapid fire” sequences) than reaching an impasse and then understanding the concepts. Attitude surveys showed that students in both institutions perceived clickers as a good tool to help them understand concepts. It seems that the students' attitude towards clickers did not depend on their backgrounds.

Minority students, due to historical reasons, are under-prepared and under-represented among college graduates relative to their proportion among the college-age population. Many efforts have been done to increase the number of minority students in higher education, especially in STEM disciplines. Yet little research has been done among mainly minority institutions, especially HBCUs on how to help minority students. This paper showed that students from SSU, a HBCU, prefer gradually learning physics concepts. It may help researchers design their question towards a predominantly minority population or students having weak science backgrounds.

ACKNOWLEDGMENTS

The authors would like to thank the Department of Engineering Technology and Mathematics at Savannah State University. The related research is supported in part by the NSF Title III STEM 360 Grant

ENDNOTES AND REFERENCES:

[a] Email: lipengf@savannahstate.edu, to whom correspondence concerning this article should be addressed.
[b] Email: lambrij@savannahstate.edu, to whom correspondence concerning this article should be addressed.

Armarego. J (2007). *Deconstructing students' attitude to learning: A case study in IT education*. Proceedings of the 2007 Computer Science and IT Education Conference, the Republic of Mauritius, November 16-18.

Crouch. C.H. & Mazur E. (2001). *Peer instruction: Ten years of experience and results* (pp. 69, 970-977). Am. J. Phys.

Draper S. W. & Brown M. I. (2004). *Increasing interactivity in lectures using an electronic voting system* (pp. 20, 81-94). J. Comput. Assisted Learn.

Dufresne R. J. (1996). *Classtalk: A classroom communication system for active learning* (pp. 7, 3-47). J. Comput. Higher Educ.

Li. P. (2007). *Creating and evaluating a new clicker methodology*. PHD thesis http://etd.ohiolink.edu/view.cgi?acc_num=osu1185575804

Pender M. (2010). *The STEM Pipeline: The Role of Summer Research Experience in Minority Students* (pp. 18, 1-34).

Peters P. C. (1982). *Even honors students have conceptual difficulties with physics* (pp 50, 501-508). Am. J. Phys.

Price E. A. & Driscoll M. P. (1997). *An inquiry into the spontaneous transfer of problem-solving skill* (pp. 22, 472-494). Contemp Educ. Psychol.

Reay N. W., Bao L., & Li. P (2005). *Toward an effective use of voting machines in physics lectures* (pp. 73, 554). Am. J. Phys.

Reay N. W., Li. P., & Bao L. (2005). *Testing a New Voting Machine Methodology* (pp. 76 (2), 171-178). Am. J. Phys.

Vasti T. & Nadal. K (2010). *Research in Brief Overcoming the Model Minority Myth : Experiences of Filipino American Graduate Students* (pp. 51, 694-706). Journal of College Student Development.