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Teaching and Learning with Clickers in Higher Education

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Interactive technologies make classroom experience more engaging and enjoyable. Students get much more involved in class discussions in the presence of such technologies and tend to learn more through student-student and student-instructor interactions. The purpose of this paper is to investigate whether student response systems (i.e., clickers) influence student learning and performance. Overall, our findings show that students were satisfied with the use of clickers especially in increasing their participation and engagement in class. A regression analysis is employed to estimate the magnitude of clickers' impact in two different disciplines. The regression results show that the use of clickers had positive and significant impact on student final course grades. In particular, students who used clickers as part of their course instruction received 4.7% higher course grades on average compared to the students in the non-clicker class when controlling for student abilities and characteristics. The outcome of this study suggests that clickers are useful tools in enhancing student learning and performance.

Technology is becoming a vital component of the modern classroom and twenty-first-century learners need twenty-first-century tools to enhance their learning. Student response systems, also known as personal response systems and "clickers," cater exactly to this need, and represent some of the best and newest educational technologies available today. These innovative assessment tools are easy to master, lead to increased classroom engagement and motivation, and can be used at any grade level.

Research on the benefits of clickers has shown that students become more engaged and enjoy using these tools (e.g., MacGeorge et al., 2008). A growing number of case studies discuss the use of clicker systems in higher education (Johnson, 2005; Johnson & Lillis, 2010; Judson & Sawada, 2002; Koenig, 2010; MacGeorge et al., 2008; Weerts, Millers, & Altice, 2009). The majority of these studies were survey based and analyzed student perceptions regarding the influence of personal response systems on their engagement (Weerts et al., 2009), motivation (Gauci, Dantas, Williams, & Kemm, 2009), and/or learning (Perkins & Turpen, 2009). In general, clickers are well accepted by students (e.g., Beckert, Fauth, & Olsen, 2009; Conoley, Moore, Croom, & Flowers, 2006).

Understanding whether clickers indeed affect student performance is important considering that clickers in most cases come at a cost to students (e.g., Bojinova & Oigara, 2011). Faculty members should be able to point to the added advantages of the use of these devices to justify their use (Bojinova & Oigara, 2011; Draper, Cargill, & Cutts, 2002; Trees & Jackson, 2007).

With clickers, students have an input device that allows them to express their views anonymously, without fear of being ridiculed by their peers in case their answer is incorrect. Each input device can be numbered or coded by the instructor for response recordkeeping. This enables the instructor to gauge students' understanding and respond according to the class needs.

The focus in higher education has shifted towards promoting student discussion of key conceptual points (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002). The current clicker software provides bar graphs or pie charts of the aggregated responses and classroom practice typically includes time for students to compare their viewpoints and possibly revise their answers following a peer discussion. This interactive engagement is seen as one of the most important benefits of personal response systems. Clickers provide added value when compared to other active learning methods such as class discussion. In a normal class discussion situation, not many students are willing to participate, especially in large classes (e.g., Biggs & Moore, 1993; Draper et al., 2002; Murphy, Walker, & Webb, 2001; Pickford & Clothier, 2003). A student who is unsure of the correct answer may be reluctant to take the risk of being incorrect. Even if the provided answer is correct, the instructor has no way to figure out if the other students know the correct answer. Clickers allow students to provide input without fear of public humiliation and without having to worry about more vocal students dominating the discussion. In Caldwell (2007), students reported that they were twice as likely to answer a question if responses were submitted by clickers. Ribbens (2007) emphasized that in the absence of personal response systems, the same students often answered the questions on a regular basis whereas clickers forced every student to answer. Miller, Ashar, and Getz (2003) using videotaped recordings of lectures with and without audio response systems showed that more student–teacher interaction was present when these systems were used. The anonymous response with a clicker guarantees almost complete if not total participation. The participation can be just a simple choice of an answer on a multiple choice question or it can involve more in-depth thinking and discussion depending on the type of the question, class setting, and time allowed to answer the question.

This paper has two main goals. First, we studied the effectiveness of using personal response systems in the classroom in terms of improving student performance. Limited research exists regarding the impact of clickers on student achievement in economics and physical geography courses as compared to, or combined with, enhanced lecture teaching pedagogy. We compared learning outcomes resulting from the use of clickers versus another active learning method such as enhanced lecturing including small group class discussions, think-pair-share activities, and utilizing question and answer strategies. Second, the present study gathered clicker feedback data from students in two courses to examine their perceptions regarding the value of this technology used across different disciplines. In particular, we examined the degree to which students believed or perceived that clickers helped them to understand the course content and perform well on their examinations. In summary, the two research questions that we investigated are:

1. Does the use of clickers benefit students and positively affect their performance?
2. How do students perceive the use of clickers in the classroom?

Literature Review

Research has shown that learners greatly benefit from the learning process when they are actively engaged (Bloom, 1984). According to Guthrie and Carlin (2004), students in 21st century classrooms are primarily active learners. The relatively new technology, clickers, offers one approach for teachers to employ active learning in the classroom. Johnson (2005) described how clickers help instructors by actively engaging students during the entire class period and providing prompt feedback to students' questions.

Although clicker systems are becoming increasingly popular in higher education, most research has been targeted mainly towards their perceived benefits, which include greater student engagement, increased student interest, and heightened discussion and interactivity. Research has shown that students enjoy using clickers in the classroom because they make an instructor's lecture both fun and interesting (Conoley et al., 2006; Duncan, 2006; MacGeorge et al., 2008; Stuart, Brown, & Draper, 2004). Studies revealed that students were able to improve their understanding of the course content and course expectations when using clickers in the classroom (e.g., Duncan, 2006). Students were also more likely to respond to questions and participate in classroom discussions when clickers were incorporated (Boatright-Horowitz, 2009; Greer & Heaney, 2004; Hoffman & Goodwin, 2006).

McKeachie (1990) and Smith (1977) found that classroom participation and discussion lead to higher-order learning. Clicker systems can be used to increase interaction and discussion among students during class time (Reay, Bao, Li, Warnakulasooriya, & Baugh, 2005). A number of researchers have hailed clickers as a mechanism for enhancing active learning (e.g., Hinde & Hunt, 2006). The latter study found that clickers improved student concentration during class meetings based on survey responses from first-year business students enrolled in an introductory economics course learning (Hinde & Hunt, 2006). McCabe (2006) identified personal response systems as useful tools to engage students through asking questions in large classes. Advocates have argued that clickers are especially effective with shy students because student responses can be collected, aggregated, and shared anonymously (Banks, 2006), though some data suggests the anonymity aspect of clickers is of little value to students (Hinde & Hunt, 2006). Taneja (2009) found that using clickers helped students achieve a higher level of learning and course satisfaction. The author indicated that the learning outcomes were significantly related to course satisfaction, immediate feedback, and active class participation (Taneja, 2009).

Fassinger (1995) found statistically significant evidence that the use of clickers can have an impact on student learning as measured by test scores. The ability of students and the instructor to engage in a dialogue around each question seemed to be very beneficial. There appeared to be much more student involvement during class time with clickers (Fassinger, 1995). Knapp and Desrochers (2009) compared the gains in terms of student post-test scores, learning, and retention scores in four different settings: interactive teaching with clickers, interactive teaching with constructed overt responding, passive teaching, and control conditions. Their findings suggest that participants performed better in the interactive conditions as compared to the other two conditions (Knapp & Desrochers, 2009). The estimated gains were higher with the constructed overt responding setting than with the clickers approach based on the comparison of the student mean scores (Knapp & Desrochers, 2009).

Majerich, Stull, Varnum, and Ducette (2011) conducted a study to determine the effect of the immediate feedback from clickers on students' achievement in a physics course. They found that the number of completed clicker quizzes was positively associated with higher achievement. In particular, the regression results indicated that, when controlling for all of the model variables, for each additional clicker lesson/quiz a student took their final grade was raised by 1.756 points (Majerich et al., 2011). The use of clickers was enjoyed by the students, lead to a better understanding of the content material, and contributed

to improved experience from this course (Majerich et al., 2011).

In another study, Lass, Morzuch, and Rogers' (2007), regression models were used with control and experimental groups to find the effect of personal response systems on student performance when utilizing variables such as average exam scores in a statistics course, cumulative GPA, high school GPA, teaching technology, and gender. The variable "teaching technology" (i.e., clickers) played an important role in student learning as measured by exam scores (Lass et al., 2007). The results of this study also suggested that nearly one-third of the final exam score could be explained by the students' performance on the teaching technology components of the course (Lass et al., 2007).

Methodology

We used the SMART Response System (PE model) in our study. To manage assessment results, plan future student instruction, and monitor class progress and understanding of the course content, teacher analysis tools are included with this system. Also available with this model is the ability to print and prepare student reports.

The study participants were the undergraduate students enrolled in three classes; two sections of Principles of Microeconomics and one section of Physical Geography in the spring of 2011 semester at a 4-year college in the United States. The Physical Geography class and one of the sections of Principles of Microeconomics utilized clickers for class discussions/reviews and/or quizzes on a regular basis. The second section of Microeconomics, which was taught by the same instructor as the clicker section, did not use clickers for class discussions, but instead incorporated other active learning techniques such as small group discussions, question and answer, and think-pair-share sessions. This section served as the control group in our study. The researchers did not have a prior knowledge about the quality of the students in the two sections of the Microeconomics course. The experimental group was chosen for its larger size following the hypothesis that it is more challenging to get a larger class engaged in active discussions. Consequently, clickers are likely to be more constructive in such a setting, as shown by prior studies.

Our research study used human subjects, and it was approved by the Internal Review Board of the college. Students received a consent form with all of the necessary details about the project. If a student was unwilling to participate in this research, they could decline on the consent form without any penalty. Those participants who wanted to take part in the interview session volunteered by providing their names and e-mail addresses at the end of the cover letter in order to be contacted by the researchers.

The total number of participants in this study was 73; 54 in the experimental (i.e., clicker) group and 19 in the control (i.e., non-clicker) group. The participation rate was very high (88% overall). The demographic data in Table 1 collected from the end-of-semester survey illustrates that the students in the two classes that utilized clickers (Geography class and one section of Microeconomics) had similar characteristics. In terms of the age distribution, the minimum and the median age in the two classes were the same (M = 18 years, Mdn = 19 years). The oldest student in the Geography class was 40-years-old whereas in the Microeconomics class the maximum age was 26. Consequently, the mean age in the former class was above the mean age of the latter class (see Table 1). The Microeconomics class had slightly more male students (47.1% versus 45%) and more freshmen (64.7% versus 55%) compared to the Geography class. The mean cumulative GPA for the prior semester of the Geography students was slightly higher than the corresponding GPA of the Microeconomics class.

The two sections of Microeconomics (i.e., control and experimental groups) were the same in terms of their minimum age and median age. The clicker class had fewer male students (47.1% compared to 52.6%), slightly lower mean cumulative GPA (2.87 compared to 2.93), and more freshmen (64.7% versus 52.6%) relative to the non-clicker class.

Table 1
Student Demographic Characteristics

	Microeconomics (clicker class)	Microeconomics (non-clicker class)	Physical Geography (clicker class)
Number of participants	34	19	20
Mean age	19.2	20.6	20.2
Median age	19	19	19
% male	47.1	52.6	45.0
% freshmen	64.7	52.6	55.0
Mean cumulative GPA	2.87	2.93	3.14

Procedure

The study started with an introduction of the SMART Response System (i.e., clickers) in the above-mentioned classes during the second week of the spring 2011 semester. Participants learned how to use the devices to respond to questions raised by the instructors. They were provided with a clicker to use in class during review sessions, for practice questions, or during quizzes. Every student in the two courses that utilized clickers was given a unique identification number to use with a clicker transmitter throughout the semester. This identification number was registered in the instructor's computer-based SMART Response database. The identification numbers were only accessible to the instructor to assess students' understanding of the subject matter, as well as to record their quiz grades in Geography. Individual student answers were confidential and never reported in class.

Students used clickers during the clicker-based sessions and returned them at the end of the class. Personal response systems facilitated the engagement of students through peer discussion. The instructors utilized clicker questions to assess students' content knowledge and as a basis for brief class discussion by raising thought-provoking questions. The following procedure was employed during a clicker-facilitated lecture. First, students logged into the clicker system by typing their unique identification number. Second, multiple choice, true/false, graphical, or numerical questions were presented on a projector screen one at a time using the SMART Notebook presentation software. Third, students were given the opportunity to collaborate with their peers so they could select an answer to that question. Fourth, students used clickers to vote for an answer, which they considered to be correct. This was done either individually or in small groups. Fifth, the instructor displayed the summary of class responses in a pie chart. Next, two approaches were incorporated: Dufresne sequence (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996) or the Mazur sequence (Mazur, 1997). According to the first approach, the pie chart displayed on the projector screen also showed the correct answer and a class-wide discussion was initiated to explain the reasons for this response. With the Mazur sequence, the pie chart did not reveal the correct answer, just the distribution of class responses. Students were given a second chance to answer the same question after a short discussion with their peers. Then, the correct answer was provided to the class and a class-wide discussion was utilized to explain and clarify that answer. In many instances the second voting improved significantly the class ability to select the correct answer.

Data Collection

Qualitative and quantitative research strategies were chosen for the study in an effort to create a more comprehensive understanding of the impact of clickers on student learning and performance. The data collected for this study included final grades, surveys, and in-depth interviews (the latter was available only for the Geography class).

The students in the Microeconomics class used clickers for practice sessions every third class period (seven times during the semester). Five of these sessions were based on a class-wide discussion, which followed a simplified version of the Dufresne sequence. Not everybody in the class received a clicker. The instructor randomly selected the participants, but usually at least 20 students had a clicker device. Thus, some students were required to share a clicker with their neighbor and discuss the question within their group. The time allocated for discussion and voting varied between 1 and 2 min depending on the difficulty of the question. Two of the practice sessions followed the Mazur sequence of peer instruction. In particular, after voting the instructor did not reveal the correct answer to this question. Only the class distribution was displayed and in a number of occasions a hint was provided to the students (e.g., "Think about what we discussed before" or "Relate the answer to the concept of . . ."). After that, students were involved in peer discussion and were asked to convince their fellow students that the answer they chose was correct. We should point out that these practice sessions were primarily used to facilitate discussions and provide feedback not only to students about their understanding of the content material but also to the instructor about the general class understanding of the important concepts. Students did not receive any points for participation as part of their class grade.

The second section of Microeconomics did not use clickers for practice sessions. The strategy for this class was to involve students in active learning through small group discussions, think-pair-share activities, and constructive feedback provided by the instructor for each review question. This class had exactly the same practice questions as the experimental section. The only difference was the method of delivery (i.e., clicker versus non-clicker sessions). The same amount of time for the review sessions was spent in both classes.

In the Geography class, clickers were used 12 times during the semester for concept quizzes. The majority of the quizzes consisted of five questions in the form of multiple choice, multiple answer, or true/false statements that covered the lecture content. For each correct answer students received one point as part of their quiz grade up to a maximum of 40 points in course credit for answering clicker questions in class.

Each of the three exams that were administered incorporated about 30% (15 questions) of the content material discussed during the clicker sessions. The questions were not exactly the same but were very similar. The instructor also used clicker sessions to clarify the material (during or after a section of a lecture). Students usually had 30 s to 60 s to answer a question. A pie chart showing the correct answer and the percentage of students who selected each answer was displayed on the screen. Afterwards, a short discussion started to explain the rationale for the correct answer, which the instructor summarized at the end. Approximately 2 min of class time was used per question. All students in the class were given a clicker device and the SMART response software recoded their responses.

Regression analysis. To measure the impact of clickers on student performance, we employed a multiple regression analysis. We used the following model to answer the question of whether clickers significantly improve student performance:

$$FinalGrade_i = \beta_0 + \beta_1 Freshman_i + \beta_2 Sophomore_i + \beta_3 Junior_i + \beta_4 EdMajor_i + \beta_5 BMajor_i + \beta_6 Clicker_i + \beta_7 Male_i + \beta_8 Age_i + \beta_9 GPA_i + \beta_{10} Eco_i + \beta_{11} FinalExam_i + \varepsilon_i$$

The dependent variable in our model was the student's final course grade measured in percentage. The independent variables included a vector of student characteristics that could potentially influence class performance (e.g., cumulative GPA of the student prior to the Spring 2011 semester, gender, class standing, study major, age, final exam grade, and enrollment in the Microeconomics class) and a categorical variable that captures the impact of clickers. The student's cumulative GPA variable captured and controlled for differences in individual abilities. GPA is not a perfect measure of student intelligence, but is a relatively good predictor of student performance in a class. We believed gender could have an impact on students' grades. In particular, Microeconomics was a course that requires good mathematical skills—both computational and graphing. Because male students usually take more math-related classes or choose majors that require more mathematical skills, they are more likely, on average, to do better than their female peers. Some studies have indicated that sex influenced geographic knowledge of individuals. Males tended to perform better than females on tests of geographic literacy and ability even when they had the same educational level (Bein, 1990; National Geographic Roper, 2002). Therefore, we included the categorical (dummy) variable *male* in the regression model which was equal to 1 if the student was male and 0 for female students.

Class standing may also affect how well students understand and learn the course material. Our reasoning was that students in their first college year tend to have very high expectations about how instructors deliver new information. In general, they expect similar teaching methods as in high school, which means much more guidance during the learning process. Therefore, some freshmen may experience difficulties understanding the course material and are more likely to drop a class as compared to junior, sophomore, or senior students. On the other hand, freshman students expect more hands-on activities during class time and consequently they will tend to enjoy more interactive technologies such as clickers. The dummy variable *freshman* was equal to 1 if a student was in their first year of college or equal to 0 if that particular student was a sophomore, junior, or senior. In a similar way, the categorical variables *sophomore* and *junior* were created. They equaled 1 if a student was in the particular year in college and 0 otherwise. The age of a student was also an important variable in this regression model. Older students were expected to behave more rationally and study more on average relative to younger students.

To control for possible differences across students from different majors, we included two categorical variables: business major and education major. If a student was a business major the dummy variable *Bmajor* was equal to 1 and equal to 0 otherwise. Similarly, if a student was an education major, the categorical variable *EdMajor* was equal to one, and for all other majors it was equal to 0. We did not have any prior expectations about the signs of the estimated coefficients on these two variables. Another categorical variable that we used in our model was *Eco*—if a student was taking the Microeconomics class this variable was equal to 1, and 0 if enrolled in the Geography class. With this variable we planned to capture differences (if available) in the abilities of students across the different disciplines.

The independent variable that was of greatest interest to us was the use of clickers (*clicker*). It was included in the model as a categorical variable taking the value of 1 if a student was in one of the classes taught with the clicker technology, or equal to 0 for the students in the non-clicker class (the second section of Microeconomics). If clickers enhanced student performance, the estimated coefficient of this variable in the model would be positive and statistically significant.

The following hypothesis was tested to see if the use of clickers had a statistically significant impact on student performance: H_0: $\beta_6 = 0$ and H_1: $\beta_6 \neq 0$. If the p value of the t test was less than the level of significance ($p = 0.01$ or 0.05), the null hypothesis would be rejected in favor of the alternative. In other words, we would

prove the alternative—the beta coefficient on the clicker variable was statistically different from zero (i.e., clickers do affect student performance). The model was estimated using ordinary least squares (OLS) with Huber-White correction of the standard errors for heteroscedasticity and correlation using the STATA software (version 10).

Results

Survey Results

To study students' attitudes towards clickers, we conducted a survey. Overall, the survey results indicated that students positively perceived clickers as a learning tool in their course. They were also pleased with the manner in which the instructors' used clickers as part of the interactive learning pedagogy. In the Geography course, 80% of the students strongly agreed or agreed with the statement that clickers made the class more enjoyable (see Figure 1). Class discussions that followed the clicker questions were perceived as beneficial to many students in understanding of the course material. All students in the course (100%) indicated that they felt more engaged in the class material and benefited from the immediate feedback from the instructor and their peers when clickers were used. Many students (80%) reported that seeing the distribution of the class responses after answering a question helped them increase their confidence in the subject. Only 45% of the students strongly agreed or agreed that the use of clickers inspired them to study more for this course (see Figure 1).

Ninety percent of the students in the Microeconomics course reported that clickers made the class more enjoyable (see Figure 2). Class discussions that followed the clicker questions were perceived by most of the students as positively affecting their understanding of the microeconomics concepts. All students in the course (100%) indicated that they benefited from the immediate feedback received from the instructor and their peers when clickers were used. Almost all (93.6%) of the students strongly agreed or agreed that they felt more engaged in the class content due to the use of this technology. Over 74% of the students noted that the distribution of class responses to a clicker question shown on the pie chart helped them to improve their confidence in the subject matter. Only 25% of the students strongly agreed or agreed that the use of clickers inspired them to study more, whereas almost 60% neither agreed nor disagreed with this statement (see Figure 2).

Interview Results

Qualitative interviewing seeks to make explicit the meaning that participants make of an experience. Finding out what is in and out of someone else's mind is a complex and sensitive task (Seidman, 1998). The purpose of the face-to-face interviews was to collect further information about respondents' experiences and the perceived value of clickers as an instructional tool. The interview guide questions were constructed to parallel themes/topics contained in the survey. The geography course instructor interviewed four volunteers about their experience with clickers. The interview results revealed that clickers added value to this course in various ways. Based on qualitative comments, several themes emerged repeatedly.

First, all of the interviewed students stated that adding sessions with clicker questions to class presentations encouraged them to read the chapters before class. Each of the interviewed students reported that the use of personal response systems increased their interest in the course and made them pay more attention during class. Participants felt that they participated more in class when clickers were used. All interviewees stated that they would prefer a class in which clickers were used. Below are some of the respondents' statements to this theme.

- "I liked that the instructor would . . . have us talk to our neighbor, figure the question out, and then by the end of the class, you had pretty much understood everything."
- "It helped me pay more attention in class."
- "I like it . . . and would prefer a class with it just because the way it is used to engage students."
- "I doubt I would have read all the chapters if there were no clicker questions, or at least I would have tried to get by without reading them."

Interviewees said that they had fun using clickers and appreciated this technology as an educational tool for class instruction. Participants reported that they liked being able to check their knowledge and comprehension of the class content, without being graded. All interviewees liked clickers because they allowed for anonymous class participation. Below are some of their comments.

- "It was anonymous so you didn't feel bad if you got the question wrong."
- "When it was used more and more people enjoyed class, . . . it just made class cool."
- "Clickers gave students a voice, even if it is not a verbal one. If we didn't have clicker questions then 2-3 people would dominate the conversation and instructor might think that whole class understood the material."

Figure 1
Survey Results in Physical Geography

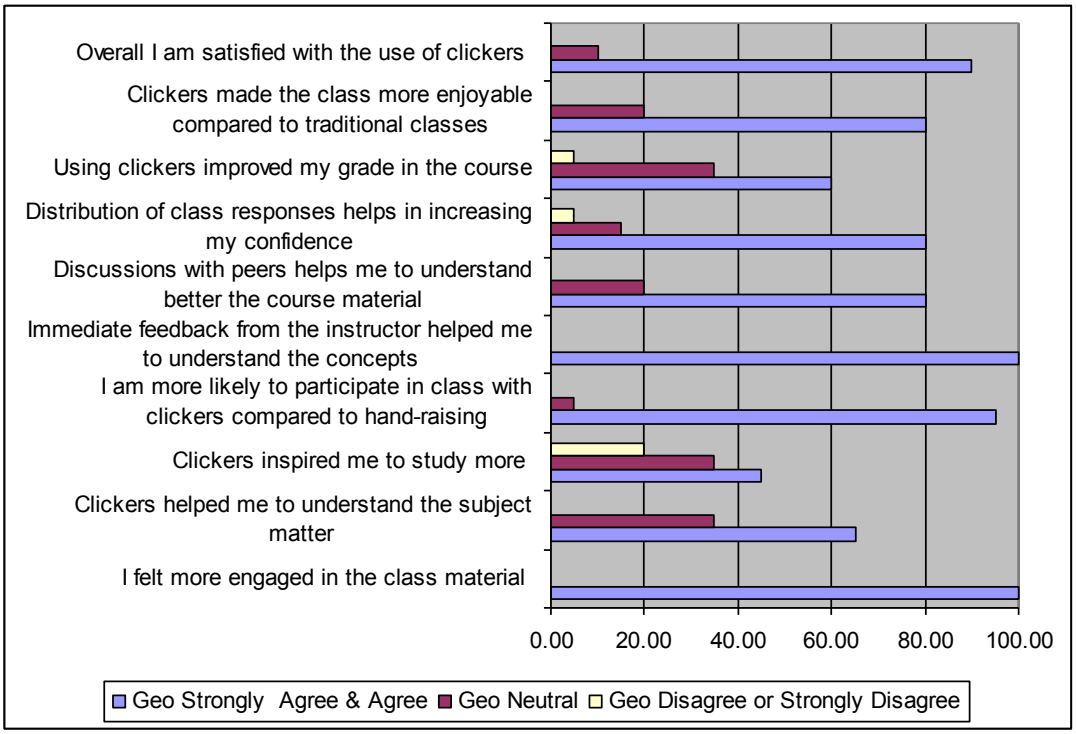
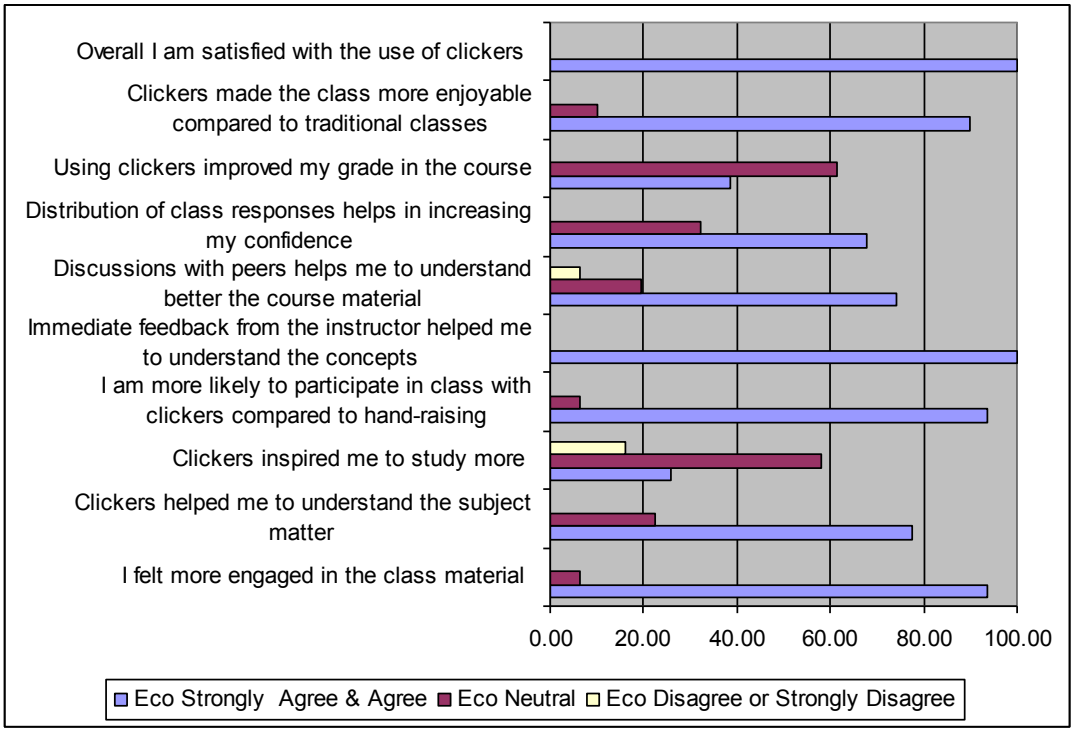


Figure 2
Survey Results in Microeconomics



The interview respondents recognized that the instructor not only used clickers to promote class discussion but also made immediate adjustments in teaching that benefited the whole class. The students also appreciated the peer-to-peer interaction. Below are quotations in support of these statements.

- "I like hearing what my classmates think and they often bring up something I didn't think of. We worked together as a whole class to figure out the answer."
- "I liked when we did the questions twice for when you were confused, you would discuss with a partner and go back and answer it again."

The interview data provide encouraging information for instructors who are considering using clickers in their courses. Adding clickers is likely to enhance peer discussion and increase the chance of having students read the chapter before class. Clickers help the instructor engage all students and give students a focused opportunity to share their thoughts and to learn from their peers.

Regression Results

One of the goals of this study was to examine the effectiveness of clickers in classroom instruction on student performance. We estimated our model described before via ordinary least squares (OLS) with Huber-White correction for heteroscedasticity and correlation. The Huber-White correction of the variance-covariance matrix of the asymptotic distribution of the OLS estimator provides consistent estimates (Greene, 1998; White, 1980). To check if the results were sensitive to outliers, we estimated the model in a log format. In particular, all of the quantitative variables were transformed into natural logarithms. The results of the main regression were not altered—the signs and the significance of the estimated coefficients were preserved. Hence, we decided to provide only the results in levels for easier interpretation.

The regression results are presented in Table 2. The estimated coefficient on the *cumulative GPA* variable was positive and significant ($p = .01$). This is consistent with our prediction that a student with a higher GPA would perform better on average. In particular, according to the regression results a 1-point increase in a student's GPA would boost their final course grade by 4.66% on average, holding the influence of the other independent variables constant. The estimated coefficient on the *age* variable was positive but not statistically different from zero. The sign of this coefficient is consistent with our expectations. The estimated coefficient on the final exam grade was positive and statistically significant ($p = .01$) indicating that student efforts had a positive impact on their course grade.

The two categorical variables, *education major* and *enrolled in the Microeconomics class*, had a negative impact on student performance. For instance, a student registered as an education major would have on average a 5.24% lower grade compared to a student from another major (ceteris paribus). Similarly, a student enrolled in the Microeconomics class, all other things being equal, would perform slightly worse than a student in the Geography class—the estimated difference was about 2.58%, but was not statistically significant. The variable *business major* turned out to be an insignificant predictor of class performance. Male students were estimated to perform slightly worse than female students regardless of the technology used and when controlling for student characteristics. However, this difference was not statistically significant.

As shown by the estimated coefficients of the *freshman*, *junior*, and *sophomore* variables, these students performed worse overall compared to the senior students. The difference was statistically significant for freshmen and juniors ($p = .05$), and marginally significant for sophomores ($p = .10$).

The clicker variable was positive and statistically significant ($p = .01$). The meaning of the estimated coefficient is that a student that used the clicker technology as part of their classroom instruction (one section of Microeconomics and the Geography class) would have a higher class grade, on average by 4.71%, relative to a student who did not utilize this technology. The R-squared value of this regression was 0.8773. In other words, the independent variables together explained about 87.7% of the variation in the final course grade.

We estimated the same regression model for the two sections of Microeconomics (control and experimental groups) to check if results were sensitive to the chosen discipline and/or the possible differences between students enrolled in Microeconomics and students taking the Geography class. The results are presented in Table 2 (specification 2). The regression results were very similar. The significance of the discussed variables did not change (excluding the dummy variables for class standing). The magnitude of the estimated coefficients was slightly different, which was not surprising. In particular, the clicker variable was positive and statistically significant ($p = .01$) as before, but the estimated impact on the final class grade was slightly stronger in this specification as compared to specification 1.

Study Limitations

We recognize that this study has some limitations. First, the survey was given only at the very end of the

Table 2
Regression Results

	All		Only Micro	
Variable	Spec.1	*SE*	Spec.2	*SE*
freshman	-4.227**	1.936	-3.589*	2.074
sophomore	-4.327*	2.475	-4.036	2.577
junior	-4.373**	2.114	-3.966*	2.116
edumajor	-5.244***	1.905	-6.992***	2.426
busmajor	1.548	1.518	1.157	1.740
clicker	4.708***	1.501	4.778***	1.470
male	-1.277	1.039	-1.050	1.138
age	0.072	0.078	0.107	0.078
GPA	4.656***	1.517	5.691***	1.624
finalexam	0.586***	0.048	0.591***	0.048
eco	-2.580	1.678	--	--
Constant	27.335***	5.437	20.575***	5.433
Observations	73		53	
R-squared	0.878		0.888	

Note. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.1$.

semester. It would be very informing to track the learning environment throughout the semester and to survey students at least at the beginning and the end of the course. Second, we are limited in determining the exact impact of the use of clickers on student performance. The measure of student academic performance was based on a single-item assessment or course grades. Likewise, it is possible that the pedagogical approach used in this study for the clicker questions, both the level of difficulty and the administration of the clicker questions, might have influenced (either positively or negatively) student performance in class. However, the results suggest that our approach using key regression variables to measure and assess the learning environment is instructive.

Third, the open-ended comments from the collected surveys suggested a number of questions that should have been included as items, such as a general score for satisfaction with clickers, questions concerning levels of students' anxiety with the technology and their learning, and questions relating to the technology itself (including perceived reliability). Lastly, although we asked students to answer survey questions honestly, demand effects might be a concern including students believing a positive response to the survey questions was the desired response. However, as explained in the results' section, student responses to some of the survey questions were negative. This does not indicate a significant demand effect bias in the survey results.

Discussion and Conclusion

This is a cross-disciplinary research that compares different pedagogical teaching techniques in different settings. The study contributes to the literature on whether the use of clickers does improve student academic performance. The findings of this study suggest that the use of clickers had a positive impact on student achievement and perceived satisfaction. Our results show that using clickers in the classroom matters in terms of improving active learning, class participation, and student academic performance. In particular, clicker questions enhanced student-student and student-instructor interaction during class. The survey data indicated that personal response systems increased student interest, class engagement, learning, and motivation. Students felt that using clicker questions created an environment where everyone in class had an opportunity to think through and answer each question that was raised by the instructors during the clicker sessions. The findings of our study are consistent with previous research on the benefits of using clickers which indicate that students learn better when they engage in appropriate cognitive processing during learning (Berry, 2009; Poirier & Feldman, 2007).

The clicker technology itself may not be the reason why learning outcomes were improved. It is a tool that facilitates active learning in the classroom. Other systems that could provide immediate feedback to the student, as well as the instructor, and also increase class interaction would potentially provide a statistically significant learning benefit. If students want to be involved and engaged they are more likely to perceive clickers positively in terms of learning, teaching, and classroom involvement (Trees & Jackson, 2007).

Our regression results provide statistically significant evidence that the use of clickers can influence student learning as measured by final grades. The use of clickers is one of the variables that significantly affected class grades in our model. By and large, we found evidence that the students who used clickers as part of their course instruction received 4.7% higher final course grades on average compared to the students in the non-clicker class when controlling for student abilities and characteristics. It is important to note that our research compares clickers' implementation in classroom instruction to other active learning teaching strategies such as small group discussions, think-pair-share, and question and answer sessions.

The findings of this study provide some evidence that the use of interactive technology in the classroom and the immediate feedback from utilizing this technology (in our case clickers) can have a positive impact on student learning as measured by the final course grades. Whether the improvement can be tied directly to the clicker is not clearly conclusive. In both sections of the microeconomics course the instructor covered identical material. However, the way the clicker section and the non-clicker class were taught might have been a contributing factor for the differences in class performance. The instructors worked very hard to make sure that in both course sections the lessons, delivery methods, and approach to teaching in the classroom were identical with the exception of the clicker sessions.

These findings are important especially in today's rapidly increasing competitive learning environment in which colleges and universities strive for retaining higher classroom enrollments in the face-to-face classes. In many college courses, instructors ask open-ended questions and call on a student to answer. However, even with such efforts, there is a potential for many of the students to be left out of the discussion, especially if they are not confident about their answer. This research found that clicker-based questions involved all students and helped them to better understand their own misconceptions about the course content. They also provided instant feedback to each student about their understanding and also a feel for what their peers know and think about the material.

The effective use of clickers has the potential to increase student engagement in a classroom setting and may serve as a tool to facilitate student active learning. Our study clearly illustrates students' positive views about using clickers, particularly regarding their usefulness in terms of student engagement, understanding of the course content, making class enjoyable or fun, and providing immediate feedback. Learning occurs when students are motivated and actively engaged in the instructional process. To facilitate student learning, instructors should be able to give prompt and appropriate feedback during instruction to help clarify student understanding of the class content as well as provide students with opportunities for interaction. Clickers as an educational tool can provide such an opportunity.

Finally, in order to better understand the full potential of clickers (Woelk, 2008), more clicker functions could be considered in combination with various learning theories. Subsequently, various instructional models could be constructed and examined using a mixed-method approach. Future research can be focused on elaborating the most and least effective approaches for the use of the clicker technology.

References

Banks, D. A. (Ed.). (2006). *Audience response systems in higher education: Applications and cases.* Hershey, PA: Information Science.

Beckert, T., Fauth, E., & Olsen, K. (2009). Clicker satisfaction for students in human development: Differences for class type, prior exposure, and student talkativity. *North American Journal of Psychology*, *11*, 599-611.

Bein, F. L. (1990). Baseline geography competency test: Administered in Indiana universities. *Journal of Geography, 89*(6), 260-265. doi:10.1080/00221349008979213

Berry, J. (2009). Technology Support in nursing education: Clickers in the classroom. *Nursing Education Perspectives, 30*(5), 295-298.

Biggs, J. B., & Moore, P. J. (1993). *The process of learning* (3rd ed.). Sydney, Australia: Prentice Hall.

Boatright-Horowitz, S. L. (2009). Useful pedagogies or financial hardships? Interactive response technology (clickers) in the large college classroom. *International Journal of Teaching and Learning in Higher Education, 21*(3), 295-298. Retrieved from http://www.isetl.org/ijtlhe/pdf/IJTLHE588.pdf

Bojinova, E., & Oigara, J. (2011). Teaching and learning with clickers: Are clickers good for students? *Interdisciplinary Journal of E-Learning and Learning Objects, 7*, 169-184.

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4-16. doi:10.3102/0013189X013006004

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *Life Sciences Education*, *6*(1), 9-20. doi:10.1187/cbe.06-12-0205

Conoley, J., Moore, G., Croom, B., & Flowers, J. (2006). A toy or a teaching tool? The use of audience-response systems in the classroom. *Techniques, 81*(7), 46-49.

Draper, S. W., Cargill, J., & Cutts, Q. (2002). Electronically enhanced classroom interaction. *Australian Journal of Educational Technology, 18*(1), 13-23.

Dufresne, R. J., Gerace, W. J., Leonard, W. J., Mestre, J. P., & Wenk, L. (1996). Classtalk: A classroom communication system for active learning. *Journal of Computing in Higher Education, 7*(2), 3-47. doi:10.1007/BF02948592

Duncan, D. (2006). Clickers: A new teaching aid with exceptional promise. *Astronomy Education Review, 5*(1), 70-88. doi:10.3847/AER2006005

Fassinger, P. A. (1995). Teacher's and students' perceptions of why students participate in class. *Teaching Sociology, 24*, 25-33.

Fies, C., & Marshall, J. (2006). Classroom response systems: A review of the literature. *Journal of Science Education and Technology, 15*(1), 101-109. doi:10.1007/s10956-006-0360-1

Gauci, S., Dantas, A., Williams, D., & Kemm, R. (2009). Promoting student-centered active learning in lectures with a personal response system. *Advances in Physiology Education*, *33*(1), 60-71. doi:10.1152/advan.00109.2007

Greene, W. H. (1998). *Econometric analysis* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Greer, L., & Heaney, P. J. (2004). Real-time analysis of student comprehension: An assessment of electronic student response technology in an introductory earth science course. *Journal of Geoscience Education, 52*(4), 345-351.

Guthrie, R., & Carlin, A. (2004). Waking the dead: Using interactive technology to engage passive listeners in the classroom. *Proceedings of the 10th Americas Conference on Information Systems*, New York, NY. Retrieved from http://www.mhhe.com/cps/docs/CPSWP_WakindDead082003.pdf

Hinde, K., & Hunt, A. (2006). Using the personal response system to enhance student learning: Some evidence from teaching economics. In D. A. Banks (Ed.), *Audience response systems in higher education: Applications and cases* (pp. 140-154). Hershey, PA: Information Science.

Hoffman, C., & Goodwin. S. (2006). A clicker for your thoughts: Technology for active learning. *New Library World, 107*(9/10), 422-433. doi:10.1108/03074800610702606

Johnson, J. T. (2005). Creating learner centered classrooms: Use of an audience response system in pediatric dentistry education. *Journal of Dental Education*, *69*(3), 378-381.

Johnson, K., & Lillis, C. (2010). Clickers in the laboratory: Student thoughts and views. *Interdisciplinary Journal of Information, Knowledge, and Management, 5*, 139-151. Retrieved from http://www.ijikm.org/Volume5/IJIKMv5p139-151Johnson445.pdf

Judson, E., & Sawada, D. (2002). Learning from past and present: Electronic response systems in college lecture halls. *Journal of Computers in Mathematics and Science Teaching*, *21*(2), 167-181.

Knapp, F. A., & Desrochers, M. N. (2009). An experimental evaluation of the instructional effectiveness of a student response system: A comparison with constructed overt responding. *International Journal of Teaching and Learning in Higher Education, 21*(1), 36-46. Retrieved from http://www.isetl.org/ijtlhe/pdf/IJTLHE499.pdf

Koenig, K. (2010). Building acceptance for pedagogical reform through wide-scale implementation of clickers. *Journal of College Science Teaching*, 46-50.

Lass, D., Morzuch, B., & Rogers, R. (2007). *Teaching with technology to engage students and enhance learning*. Retrieved from http://www.cengage.com/owl/site/Teaching_with_Technology%20to%20Engage%20Students%20and%20Enhance%20Learning.pdf

MacGeorge, E., Homan, S. R., Dunning, J. B., Elmore, D., Bodie, G. D. Evans, D., . . . Lichti, S. (2008). The influence of learning characteristics on evaluation of audience response technology. *Journal of Computing in Higher Education, 19*(2), 25-46. doi:10.1007/BF03033425

Majerich, D., Stull, J., Varnum, S., & Ducette, J. P. (2011). Facilitation of formative assessments using clickers in a university physics course. *Interdisciplinary Journal of E-Learning and Learning Objects, 7*, 12-24.

Mazur, E. (1997). *Peer instruction: A user's manual*. Englewood Cliff, NJ: Prentice Hall.

McCabe, M. (2006). Live assessments by questioning in an interactive classroom. In D. A. Banks (Ed.), *Audience response systems in higher education: Applications and cases* (pp. 276-288). Hershey, PA: Information Science.

McKeachie, W. (1990). Research on college teaching: The historical background. *Journal of Educational Psychology, 82*(2), 189-200. doi:10.1037/0022-0663.82.2.189

Miller, R. G., Ashar, B. H., & Getz, K. J. (2003). Evaluation of an audience response system for the continuing education of health professionals. *Journal of Continuing Education in the Health Professions, 23*(2), 109-115. doi:10.1002/chp.1340230208

Murphy, D., Walker, R., & Webb, G. (2001). *Online learning and teaching with technology: Case studies, experience and practice.* London, UK: Kogan Page.

National Geographic Roper. (2002). *National geographic roper 2002: Global geographic literacy survey*. Washington, DC: National Geographic Education Foundation.

Perkins, K., & Turpen, C. (2009). Student perspectives on using clickers in upper-division physics courses. *Proceedings of the Physics Education Research AIP Conference, Boulder, CO, 1179*, 225-228. doi:10.1063/1.3266721

Pickford, R., & Clothier, H. (2003). *Ask the audience: A simple teaching method to improve the learning experience in large lectures*. Retrieved from http://www.academia.edu/284132/Ask_the_Audience_A_Simple_Teaching_Method_to_Improve_the_Learning_Experince_In_Large_Lectures

Poirier, C. R., & Feldman, R. S. (2007). Promoting active learning using individual response technology in large introductory psychology classes. *Teaching of Psychology, 34*(3), 194-196. doi:10.1080/00986280701498665

Reay, W. R., Bao, L., Li, P., Warnakulasooriya, R., & Baugh, G. (2005). Toward the effective use of voting machines in physics lectures. *American Journal of Physics*, *73*(6), 554-558. doi:10.1119/1.1862638

Ribbens, E. (2007). Why I like personal response systems. *Journal of College Science Teaching, 37*(2), 60-62.

Seidman, I. (1998). *Interviewing as qualitative research*. New York, NY: Teachers College Press.

Smith, D. (1977). College classroom interactions and critical thinking. *Journal of Educational Psychology, 69*(2), 180-190. doi:10.1037/0022-0663.69.2.180

Stuart, S. A. J., Brown, M. I., & Draper, S. W. (2004). Using an electronic voting system in logic lectures: One practitioner's application. *Journal of Computer Assisted Learning, 20*(2), 95-102. doi:10.1111/j.1365-2729.2004.00075.x

Taneja, A. (2009). The influence of personal response system on students' perceived learning outcomes and course satisfaction. *Journal of Circuits, Systems and Computers, 25*(2), 5-11.

Trees, A., & Jackson, M. (2007). The learning environment in clicker classrooms: Student processes of learning and involvement in large university-level courses using student response systems. *Learning, Media and Technology, 32*(1), 21-40. doi:10.1080/17439880601141179

Weerts, S., Miller, D., & Altice, A. (2009). "Clicker" technology promotes interactivity in an undergraduate course. *Journal of Nutrition Education and Behavior*, *41*(3), 227-228. doi:10.1016/j.jneb.2008.08.006

White, H. (1980). A heteroscedasticity-consistent covariance matrix estimator and a direct test for heteroscedasticity. *Econometrica, 48*(4), 817-838. doi:10.2307/1912934

Woelk, K. (2008). Optimizing the use of personal response devices (clickers) in large-enrollment introductory courses. *Journal of Chemical Education, 85*(10), 1400-1405. doi:10.1021/ed085p1400

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