Clickers, Student Engagement and Performance in an Introductory Economics Course: a Cautionary Tale

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Abstract

We examine whether clickers affect learning in an introductory economics course when introduced on a limited 'quizzing' basis in a traditional lecture course. Based on early and end of semester surveys, we assess whether clickers are associated with changes in student course performance or changes in student engagement. Using an education production function that controls for student GPA, etc., we find no significant differences between the clicker and nonclicker sections in student attitudes toward attendance, participation or class engagement, nor do we find any difference in exam performance. We conclude instructors should be cautious patching new technologies into traditional lecture courses, and universities cautious in mandating technology use.

Introduction

As educators, we often ask ourselves 'are our students actually learning from our classroom lectures?' Most educators feel that student participation in class contributes to better mastery of the course material, and therefore, many are willing to invest in new technologies and teaching methods in the hope that they will improve both learning and engagement. However, few studies document the limitations of the use of such technologies, especially when the technology is 'patched' into an existing class format. In many ways, this creates a false sense that all new technologies lead to improvements in the classroom; more concerning is the impression that the use of new technologies can be substituted for thoughtful pedagogical preparation. As universities and colleges are increasingly issuing top-down directives to increase the use of new technologies in the classroom (see Bachelder, French and Lichti, 2006, for example), fair evaluation and reporting on these classroom technologies is important.

One new and appealing technology is 'clickers' or classroom response systems.[1] Clickers are handheld devices that allow students to transmit numbers and/or letters to a classroom computer. Each student clicker is individually recognised by the computer, and all student responses are recorded by the system. Thus, the clicker can be used in several different ways: to survey students, to ask questions and to randomly call on students. Duncan (2006) characterises the clickers as an 'exceptionally promising' new classroom tool, and Wood (2004) concludes that clickers are a 'gimmick that works'.

Perhaps the most common use of clickers is to address the incongruity between the financial necessity of large classes and the desire to engage students individually in the learning process (Judson and Sawada, 2002; Ober, 1997; Sharma *et al*., 2005; Wood, 2004). Initial studies examining clickers have been encouraging, though few comment directly on using clickers in economics or business courses (for an exception, see Elliot, 2003; Freeman and Blayney, 2005). Several studies have looked at whether clicker systems can make a difference in the classroom atmosphere (Beatty, 2004; Draper and Brown, 2004; Duncan, 2006; Gutherie and Carlin, 2004; Freeman and Blayney, 2005; Knight and Wood, 2005; Len, 2007; Stuart, Brown and Draper, 2004). The studies find that clicker use appears to increase active learning by creating more interactive lectures and quizzes, along with providing students with immediate feedback. Anecdotally many of these studies find that faculty using clicker systems report greater student engagement in the classroom, high satisfaction and gains in student learning across the disciplines.

In this study, we examine whether patching clickers into a lecture-oriented introductory microeconomics course can improve student performance and engagement. Our motivation was to add an interactive element to the traditional 'chalk and talk' format of most introductory economics classes (Becker, Becker and Watts, 2006), without investing in significant course reform. A secondary motivation was to participate in the campus-wide initiative

to support more extensive clicker use in large-lecture classes. The institutional rationale is that increased use would both improve student clicker proficiency and reduce the average cost for students, as the fixed clicker and activation costs could be spread across more classes. While the cost and user benefits may still accrue to students, we find no identifiable impact on student course performance or engagement. We conclude instructors should be cautious about patching new technologies into traditional lecture courses, and universities should be cautious in mandating technology use.

Methodology

Classroom response systems

The clickers used in this study operate very much like television remote controls. Students each have a small handheld device with a panel of numbers and letters; the device transmits radio signals to a classroom receiver that in turn communicates with the classroom computer. Each student's response is individually recognised and recorded by the computer. Clicker questions can be multiple-choice, true–false, matching or numerical. Students are asked a question, they enter their responses on their clickers, and the aggregate results are immediately displayed either as a table or a histogram. This allows students to see, not only if they answered correctly, but also how their response compares to their classmates. This information can then be used to clarify lecture material or stimulate class discussion or some type of collaborative learning.[2]

In addition to fostering participation and discussion, studies have documented that clickers are very suitable for quizzing (Byrd, Coleman and Werneth, 2004). The advantage of clickers is the immediacy of feedback. With traditional paper assignments, students must wait for feedback, as instructors cannot afford to waste valuable class time on evaluating questions and recording grades. The delay in returning coursework to students, however, means that students may forget questions or lose interest.

We incorporated clickers into introductory microeconomics in two ways. First, the instructors used the clickers to ask questions in class. Some of these questions were surveys; for example, asking students whether they were in favour of free trade or if they would buy a product at a particular price. All students would 'click' in their answers which would then be automatically tabulated; in the nonclicker classes, the instructors would simply ask for a show of hands. Other questions asked were multiple-choice, similar to quiz or exam questions, checking for student mastery of material. Students received no points, but were strongly encouraged to participate. We should note that one important difference is that while in the nonclicker sections instructors would ask questions and wait for a *single* student to volunteer to answer, in the treatment sections *all* students had the opportunity to answer the question by using their clicker.

The second way clickers were incorporated into the class was for quizzing. Students in the clicker sections were required to use the clickers to complete their quizzes. In contrast to the traditional quiz format, in the clicker sections students received immediate feedback as to their performance on quiz questions. The process was as follows. For each question of a weekly ten-question quiz, students were given between one and two minutes to answer the question. Once the question was timed-out, the correct answer was immediately displayed, along with the distribution of student responses. Depending on the distribution of answers, instructors would then review how to correctly solve each problem, and students would have the opportunity to ask questions. Students in the nonclicker sections completed their quizzes on paper and had to wait one class period to receive their scores and ask questions. All four sections had identical quiz and exam questions (though questions and answers were sometimes scrambled).

The two instructors in this study had no prior experience in using clickers. Both instructors used quizzes as incentives for the students to be prepared for and attentive in class. Excepting quiz delivery, there was very little difference between the clicker and nonclicker courses, both of which primarily used the traditional lecture mode of class organisation.

Study methodology and data

Introductory microeconomics is one of several pre-core business courses at our regional public university, located in the midwest United States. All aspiring business and economics students must complete the course. Because of this, introductory microeconomics classes are among the largest in the pre-core business and economics curriculum. As previous research has suggested that use of clickers may be most effective in larger courses (Ober, 1997; Sharma *et al.*, 2005), we anticipated that we might be more likely to see improved student performance and engagement in introductory microeconomics compared to other economics courses.

To test whether the use of clickers affects student perceptions of student engagement or exam performance at our university, we examined four sections of introductory microeconomics taught by two different instructors. Each microeconomics instructor had one section randomly assigned as a control (nonclicker) and one section randomly assigned as a treatment (clicker). Students had no foreknowledge of whether or not they would be using clickers. Using a survey, data were gathered on students enrolled in the four sections during the spring 2006 semester. All sections had enrollments of 45 to 55 students. Students were asked to provide background and demographic information including their gender, race, age, university class status, study habits, attendance patterns and mathematics background. These data were supplemented by university data on grade point average (GPA) and collegiate entrance exam (ACT) score. See Figure 1 for a summary.

Our initial sample consisted of 202 students who were enrolled in the course at the beginning of the semester. Resampling at the end of the semester yielded 157 usable responses (78% of registered students). The students were primarily sophomores (44%) with a mean GPA of 2.82 and a mean ACT score of 22.7.[3] The sections were 38% female

Figure 1. Summary of background and demographic data

	Percent	Mean	Standard Deviation
Female	38.37		
Male	61.63		
Age		20.63	4.27
Freshmen	23.58		
Sophomores	44.19		
Juniors	22.67		
Seniors	6.40		
Other	1.16		
Non-minority	88.95		
Minority	11.05		
Hours Work per Week	13.77	11.55	
Hours in Extra Curricular Activities		4.52	5.76
Weekly Hours Study for all Classes		10.19	7.01
Course is Required for Major	82.35		
Not Required for Major	17.65		
GPA		2.81	0.54
Composite ACT Score		22.65	3.47
Enrolled in a 'Clicker' Section	52.33		
N = 157			

and 89% of students classified their race as 'white.' Overall, 82% of students were taking the class because it was required for their major. Because of the impossibility of randomly assigning students to clicker and nonclicker sections, we carefully examined the data collected for bias. We find very few statistically significant differences in attributes between students enrolled in clicker and nonclicker sections. The two exceptions are: that students in the clicker sections had higher GPAs, averaging 0.16 of a grade point more than students in the nonclicker sections (p = 0.02); and students in the nonclickers section reported studying approximately two more hours a week, on average, than students in the clicker sections (p = 0.03). There were no statistically significant differences in the characteristics of students between the classes of the two professors.

To minimise student non-response, we gave the survey on the first day of class. Students not attending the first day are automatically dropped from the course at our university. This policy results in near perfect first day attendance. The follow-up survey was given on a quiz day, two weeks before the end of the semester. Students absent on the quiz day were asked to voluntarily fill out the survey during the next class.[4] Some other students had missing data for several different reasons. On some survey questions, students occasionally chose an invalid option or left the question blank. Overall, we were missing responses for roughly 19% of students, including those who failed to fill out the follow-up survey and those who dropped the course. For some of these students, we replace the missing values with sample mean values in an effort to preserve the sample size.

In addition to background and demographic questions we also asked students a series of questions assessing their views on the merits of class attendance, participation, engagement and reading the textbook. Students were resurveyed at the end of the semester on a number of similar questions and t-tests of means are conducted to compare student answers for the clicker and nonclicker sections. Students in the clicker sections were also asked several questions specifically relating to the clickers. Summary statistics for these questions are reported in Figure 2.

Evaluation

Examining clickers and student engagement

The early and late semester surveys yielded a number of interesting insights into the attitudes and behaviours of introductory economics students. For example, compared to the beginning of the semester, students were statistically significantly more likely to think that attendance was positively correlated with grade earned in the course at the end of the semester (p < 0.01). However, at the same time,

Figure 2. Student engagement

	Beginning of the Semester Responses Control*	End of the Semester Responses Control*	Beginning of the Semester Responses Clicker*	End of the Semester Responses Clicker*
Will attendance help you earn a higher grade?				
• Yes	81.93	96.83	84.44	92.31
• No	18.07	3.17	15.56	7.69
Will participating help you earn a higher grade?				
• Yes	87.95	68.25	82.22	62.82
• No	12.05	31.75	17.78	37.18
Should professors require attendance?				
• Yes	33.73	30.16	38.89	26.92
• No	66.27	69.84	61.11	73.08
Should professors require course participation?				
• Yes	21.69	19.05	17.78	21.79
• No	78.31	80.95	82.22	78.21
Will reading the chapter before class help you earn a higher grade?				
• Yes	93.98	84.13	91.11	76.92
• No	6.02	15.87	8.89	23.07
How often did you [plan to miss] or [actually miss] your economics class this semester?				
• Fewer than 3 times	65.06	69.84	56.67	67.95
• Between 3 and 5 times	27.71	26.98	35.56	23.08
• Between 5 and 10 times	7.23	3.17	3.33	7.69
• Between 10 and 15 times	–	–	2.22	1.28
• I rarely attend, except for exams	–	–	2.22	–
End of the Semester Questions Only				
I was engaged in this course.				
• Yes		36.51		34.62
• Somewhat		53.97		55.13
• No		9.52		10.26
This class was boring.				
• Yes		6.35		11.54
• Somewhat		44.44		41.03
• No		49.21		47.44
Using clickers helped me pay attention in class.				
• Yes		–		47.44
• Somewhat		–		41.03
• No		–		11.54

* Responses are reported as the per cent of the total.

** There were few statistically significant difference between the clicker and nonclicker sections overall, nor between beginning and end of the semester responses. One exception is that students in the clicker sections felt more negatively about reading before class at the end of the semester than they did at the beginning of the semester (p = 0.03).

students at the end of the semester believed that participation did not help them earn a higher grade. We also observe a decline in the number of students who believe professors should require attendance or participation, and whether reading the textbook before class is helpful, over the course of the semester. These differences are all statistically significant at the 10% level or better (see Figure 2). We hypothesise that these differences may have to do with the preconceived notions students may have about economics. When these preconceptions are not validated through experience, the students may report that they did not find participation or reading the textbook helpful. A second explanation may be due to the clickers themselves. Students may have substituted the feedback from the clickers for careful reading of the textbook. They also may not have considered using the clickers as a form of class participation. For example, Guthrie and Carlin (2004) found that based on log information class participation using the clickers was 95%, but when asked, less than half of the students believed they were participating more in class. A third possible explanation may relate to students' transition from freshmen to sophomores – as students become both more savvy in their studying and course preparation, they may find that certain behaviours are not as beneficial as they had previously thought, or that the opportunity cost of pursuing such behaviours, e.g. giving up some of the social aspects of college life, exceeded the payout.[5]

In general, we find that students felt they were engaged or somewhat engaged in the course, with nearly 90% of students reporting that they were 'engaged' or 'somewhat engaged,' though no difference was found between the clicker and nonclicker sections. Approximately 6.45% of nonclicker students and 11.5% of clicker students reported that they found the course boring; the difference was not statistically significant.[6] However, over 88% of students agreed either strongly or somewhat with the statement that 'using clickers helps me pay attention in class'. We find these results encouraging, especially as our university has scored poorly on the National Study of Student Engagement (NSSE). However, reported engagement is highly correlated with GPA. In both the clicker and nonclicker sections, students with higher GPAs claim higher levels of engagement, as is apparent in Figures 3 and 4.[7]

While there is no statistically significant difference in reported engagement, class liveliness or the worth of class attendance between the clicker and nonclicker sections, students in the clicker sections felt that participation was more valuable than students in the nonclicker sections ($p = 0.10$). Thus, while we cannot document a clear impact of the clicker on student-reported course expectations or engagement, anecdotally, the professors observed a difference in students' response to the quizzes. In the clicker section the immediate feedback led to more and better discussion of the quiz questions than in the control section. Students in the control sections were encouraged to ask questions about the quiz, but very few took advantage of the opportunity. This is important as Kirkwood and Price (2005) discovered the perception that using technology positively affects education more significantly than the actual characteristics of any particular type of technology.

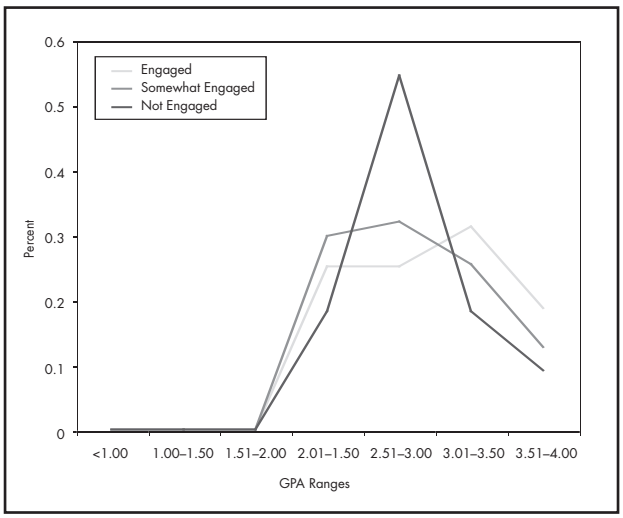

Figure 3. Student-reported engagement in clicker sections

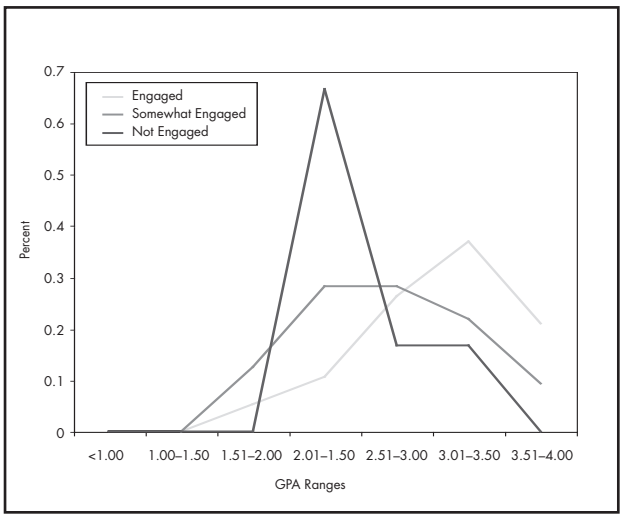

Figure 4. Student-reported engagement in nonclicker sections

Overall, we find that student views of engagement and participation are most directly linked to student academic performance. While there is no statistically identifiable difference between the students in the clicker and nonclicker sections, students with higher GPAs consistently reported higher levels of engagement and satisfaction with the course.

Clickers and student exam performance

We are also interested in whether clickers can be associated with improved student performance in introductory microeconomics. In Figure 5, the distribution of the percentage of questions answered correctly on the three course exams is examined. Students are grouped into two categories: those in treatment sections (Clicker Series) and those in the control sections (Nonclicker Series). At first pass, it seems that students in the clicker sections preformed more poorly relative to the nonclicker section at the lower end of the question distribution, but performed better at the upper end of the distribution. Kennedy and Cutts (2005) also found a positive association between clicker usage and learning outcomes for students who are, relative to their class, of higher ability. They further found

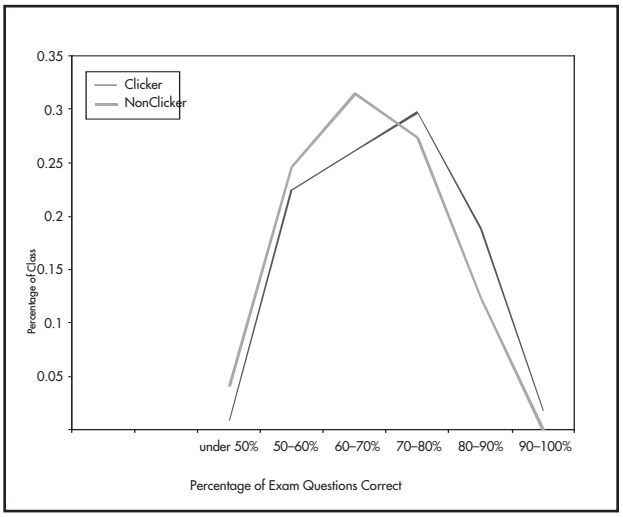

Figure 5. Grade distributions for the clicker and nonclicker students

students who were more likely to respond incorrectly to clicker questions throughout the course tended to perform poorly on exams regardless of whether they were high or low responders. However, it might also imply that the clickers helped students who took advantage of the technology, but actually hurt those who did not take it seriously. Finally, the results may also reflect the correlation between class attendance and participation on student performance. A student who misses class consistently or does not pay attention in class will tend to perform poorly on the exams. Kennedy and Cutts (2005) discovered that students who did not use the clickers, for whatever reason, and were considered high-ability students did relatively worse on exams than comparable students. As noted earlier clickers require students to take more responsibility for their learning and those that do not are bound not to do as well in the course.

A t-test of means suggests that students in the clicker sections scored a quarter of a standard deviation higher (2.5 to 3 percentage points more exam questions correct) than students in the nonclicker sections ($p = 0.04$) over the course of the semester, not controlling for other factors. The difference varied significantly across professors. In Professor 1's sections, there were no statistically significant differences between groups. However, in Professor 2's sections, the clicker students scored, on average, 0.4 of a standard deviation higher than the nonclicker section ($p = 0.01$).

To more carefully explore the relationship between the use of clickers and student performance, we estimate an educational production function, as developed by Hanushek (1979). This model suggests knowledge is produced out of a variety of student motivational and background variables as well as university and instructor specific variables. Thus, we speculate that the dependent variable for each student, *i*, depends on a student's background (gender, race, university class), the student's level of engagement with the class (attendance, participation), intelligence (GPA, ACT score), effort (hours spent studying, working) and whether or not students used clickers in the course.

We define our dependent variable as the standardised percentage of exam questions answered correctly by a student; this is found by taking a student *i*'s percentage of exam questions answered correctly minus the mean for instructor *j*, divided by the standard error for instructor *j*. While the two microeconomics professors gave identical multiple-choice exams, to control for any potential differences in grading or awarding of points across professors, standardisation seemed the most expedient remedy.[8]

$$\textit{Standardised percentage exam questions correct}_i = \frac{\textit{\% exam questions correct}_i - \textit{mean\%}_j}{SE_j}$$

We estimate the following:

$$\textit{Standardised percentage exam questions correct}_i = f(\textit{background}_i, \textit{engagement}_i, \textit{intelligence}_i, \textit{effort}_i, \textit{clicker}_i)$$

We report the results of the OLS regression analysis in Figure 6. In general we find that students' gender, GPA, ACT exam score and maths background significantly affects the percentage of questions a student answered correctly throughout the semester.[9] The interpretation of the estimated coefficients requires some explanation; since the dependent variable is standardised percentage of questions answered correctly, the coefficient estimated is a standard deviation measure. For most students, the range of the percentage of exam questions answered correctly was from roughly 45% to about 90%. The overall mean number of questions answered correctly was 68%, and the standard deviation was 11%. Thus, a change of one standard deviation is equivalent to a change of 11 percentage points.

Across all sections, females answered roughly one-half of a standard deviation fewer questions correctly than males, or earned roughly 5.5 percentage points fewer in the course. Unfortunately, this is a common result in the economics literature examining American students (Ballard and Johnson, 2005; Walstad and Robson, 1997). An additional grade point is associated with more than one standard deviation improvement in the course (approximately 11 percentage points, or about one letter grade, as would be expected). Further, for each extra point earned on the ACT exam, students could expect to improve their exam score by slightly more than 1/20th of a standard deviation (or 0.7 of a percentage point). Students who had been required to take a remedial or developmental mathematics course scored, on average, nearly a quarter of a standard deviation below their peers, other factors held constant.[10] Sophomore or second-year students, taking the course on schedule, scored a quarter of a standard deviation higher than other students. There were no statistically significant differences based on hours worked or studied, or whether a student was of minority heritage.

While we examine the relationship between a number of student attitudinal variables and student course performance, the only variable with a statistically significant effect on course performance is student self-reported engagement. Students who reported at the end of the semester that they were engaged in the course scored on average 0.31 of a standard deviation higher than students

Figure 6. Regression results (dependent variable is standardised percentage of exam questions answered correctly)

Explanatory Variables	Estimated Coefficients†
Female	-0.526 (0.131)***
Sophomore	0.236 (0.123)*
Minority (non-White)	0.066 (0.209)
Hours Work per Week	0.003 (0.005)
Hours Study per Week	0.003 (0.009)
Required to take Developmental Mathematics	-0.302 (0.182)*
University GPA	0.969 (0.134)***
ACT – Collegiate Entrance Exam Score	0.053 (0.019)***
Clicker Section	0.022 (0.127)
Reported Being Engaged	0.307 (0.131)**
Constant	-3.635 (0.627)***
N, R-Squared	N = 157, R-Squared = 0.499

† Numbers in parenthesis are standard errors. Significance level is indicated * = 10%, ** = 5%, and *** = 1 %.

who reported being 'somewhat' or 'not at all' engaged. This translated to an increase of 3.4 percentage points in the course, holding GPA and other variables constant.

However, perhaps the most interesting result is that, controlling for other factors, students in the clicker sections did no worse or better than students in the nonclicker sections. This result is highly robust, and in contrast to previous findings (Byrd, Coleman and Werenth, 2004; Sharma *et al.*, 2005).

Discussion

In most economics courses, lectures have typically been used to guarantee that all the 'required' material is covered (Becker, Becker and Watts, 2006). Often, there is considerable pressure to cover a certain amount of material, in order to prepare students for the next level of instruction. It is therefore difficult convincing instructors to take the time to learn and use new technologies, even if (or because) it is decreed by the administration. In this article, we examine how introducing 'clickers' to a lecture-based introductory microeconomics course on a limited basis affects student performance and engagement.

Our study suggests that simply patching clickers into a lecture course does not result in statistically significant improvements in student performance or attitudes. This should not be surprising since Judson and Sawada (2002) surveyed the literature of the 1960s and 1970s that used technology with traditional lecture approaches and found that student performance, despite student satisfaction with the technology, showed no differences.

Our findings should be cautionary from three different perspectives. First, universities mandating adoption of certain technologies should be very careful to examine how such technologies are used in the classroom. Patching clickers onto courses without corresponding pedagogical changes is unlikely to improve student performance. Certainly, there are university-wide advantages to the extensive use of clickers, since there are several different systems and packages available.[11] Adoption becomes a university-level decision for a standardised system, which also allows opportunity to negotiate reasonable fees. In this way clicker systems are subject to economies of scale; the more instructors that use them, the lower the overall cost to the student. University-wide adoption may prove additionally compelling: as the research shows, the more

exposure and experience both teacher and students have, the better the results from using the clickers

A secondary caution is that the effectiveness of clickers may depend significantly on the type, organisation and size of the course. In large classes (e.g. greater than 100 students) it is much easier for students to shirk their learning responsibilities when they are one of a multitude. Clickers require that everyone actively responds to all the questions, so it is difficult to 'hide in the back row'. Several studies report students like the anonymity clickers provides. Kennedy and Cutts (2005) showed students were twice as likely to attempt answering questions when using clickers as when being required to answer verbally or by putting up their hands. While the classes involved in this study were large compared to other economics courses at our university, a class size of 50 may not be sufficiently large to generate benefits.

The final caution is that students may not always understand the significance of engagement and participation in the learning process. Instructors can play a significant role in facilitating their understanding by explaining and illustrating how clickers can be utilised to enhance their learning. As with anything new, it takes a while to get used to it, accept it and improve on its use. Two areas of concern that may influence the effectiveness of the clickers include the time cost of using them and the learning curve required for both students and instructors to become familiar with the new technology. Studies have shown that the successful use of technology depends in part on student learning styles (Manochehr, 2006).

Besides the out of pocket expenses, students found clickers required them to devote more time and effort to their classes than they would otherwise. Wood (2004) observed that some of students did not like the clickers because they found it necessary to attend class and to pay attention in order to receive participation points. Furthermore, Duncan (2006) emphasises that using clickers requires more work for students than just taking notes. From an instructor perspective learning to implement new technology into the classroom also requires more time and effort. Guthrie and Carlin (2004) found instructor competence with the use of clickers is an important factor in contributing to student perceptions of their value. While clickers are relatively easy to use, instructors need to create well-organised questions for use with the technology and that it needs to be fully integrated into the course, implying modifying currently used pedagogies.

As universities and colleges are increasingly issuing directives to increase the use of new technologies in the classroom, believing they will improve student learning and lower teaching costs, fair evaluation and reporting on these classroom technologies is crucial for making informed decisions about their adoption. The ubiquity of studies reporting classroom gains from the adoption of new technologies creates an illusion that all new technologies lead to improvements in the classroom. This is probably not the case; new technologies must be accompanied by adjustments in teaching style and pedagogy in order to be effective.

Notes

1 Clickers are classroom response systems (CRS), also referred to as audience response systems (ARS), classroom communication systems (CCS), classroom performance systems (CPS), electronic voting or response systems (EVS, ERS), group response systems (GRS) and student response systems (SRS).

2 The clickers used in this study are those supported by E-Instruction. A more detailed and technical description of the variety of clickers available and how they work can be found in Holland and Lide (2006).

3 As is typical of most American universities, student grade point average (GPA) is calculated on a four-point scale, ranging from zero (an F) to 4.0 (an A). The ACT exam is similar to the Scholastic Aptitude Test or SAT, except that the ACT is comprised of four parts, rather than two. The ACT includes sections on mathematics, English language, reading and science/reasoning. From these four sections, a composite score is calculated out of 36.

4 In an effort to control for the non-random assignment of students among sections, we collected information as to whether the student was enrolled in their first-choice of section. Overall, 85.23% of students enrolled in their preferred section. However, this variable has insignificant coefficients and t-statistics in the performance regressions and is thus not included in the final reported results.

5 A series of ANOVA tests were performed, attempting to ascertain whether there were any patterns in the students who reported that attendance, class participation and reading the chapter in advance were less important at the end of the semester than at the beginning. No pattern emerged, as F-tests showed no statistically significant relationships between these questions and GPA, ACT score, student gender or student age.

6 Byrd *et al*. (2004) recommend that when using a teacher-managed quizzing mode no more than five questions should be asked; if using a student-managed mode, more questions can be asked. Our quizzes were ten questions, and were administered using the teacher-managed mode.

7 In fact, in a regression with engagement as the dependent variable, no student demographic characteristics were statistically significant other than university reported GPA.

8 Since the dependent variable is standardised across each individual professor, it is not necessary to include a dummy variable for professor.

9 However, many additional variables were included in different regression specifications and failed to pass an F-test of inclusion. Those variables were left out of our reported regression. In addition, we attempt a number of different specifications, but find the following results are highly robust.

10 All introductory microeconomics students at our university are required to have completed business calculus; given the homogeneity in student experience, we find that variables indicating whether students have taken calculus or business calculus are not statistically significant in regressions of student performance.

11 The choice of system package can be of importance to student acceptance of the technology. The clickers used in this study have since been updated to include an LCD display. With the new clickers, there have been fewer student complaints about the technological difficulties, which can affect student attitudes toward the technology.

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