Do Daily Clicker Questions Predict Course Performance?

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Abstract

The use of classroom response systems is growing, because they promote more active student engagement, especially in large classes. Students like using clickers for formative assessment and students think clickers help them to learn. But do they? This paper provides evidence that student performance on daily formative clicker questions is a key variable in predicting summative assessment of student learning in small Principles of Microeconomics classes even after controlling for other predictors.

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Teachers prefer attentive students who show some evidence of wanting to learn. Students prefer classes that are interesting and even fun. Questions posed during class using a classroom response system (clickers) can help both teachers and students get what they want. It's not just that some students will wake from lethargy periodically to answer a question. Students begin to anticipate questions, which encourages them to be more actively engaged in learning between questions. Clicker questions can help make formative assessment seem like a game to students, so there is much evidence that students like using clickers. There is even evidence that students *think* that clickers help them to learn.

For centuries instructors have asked questions to help students to learn. Classroom response systems use hand-held "clickers" for students to answer multiple choice questions posed by the instructor. Because this approach allows all students to participate and to do so anonymously, it has been used for at least forty years.

The use of clickers to promote active learning was pioneered in physics education. Some studies have demonstrated that active learning as facilitated by clickers has enhanced student learning. However, these studies have neglected the impacts of other student characteristics on summative assessments. The use of clickers in economics classrooms is much more recent than their use in physics education. However, economists have developed a more extensive literature on the effects of various student characteristics on measured student learning. We take a first step toward merging these two streams of thought.

Many other predictors of student learning have been identified in the economics literature. Does the use of clicker questions actually help students to learn economics after things like ACT/SAT scores, prior college GPA and measures of math skills are considered? We present early evidence that student performance on formative clicker questions is indeed an important predictor of summative assessment even after controlling for other important predictors of student learning.

Literature

In an early study using an anonymous feedback system Rubin (1970) demonstrated that students were more willing to admit confusion in class if they could do it anonymously. Chu (1972) reported on the uses of a student response system in a single small classroom dedicated for this purpose. However, classroom response systems were not widely used before Mazur (1997) advocated their use to promote active learning in large introductory college physics courses.

Chu (1972) reported that faculty found an early student response system to be only moderately useful, and student ratings were even lower, largely because the equipment used was cumbersome. But Judson and Sawada (2002) reported that most early studies found students favoring electronic response systems. The thing most widely reported recently is how much students like the use of class response systems for formative assessment (Draper and Brown 2004; Banks 2006; Caldwell 2007; MacGeorge, et al. 2007, Trees and Jackson 2007; Gormley-Heenan and McCartan 2009). In particular, students like getting feedback on their understanding in a setting where their errors can remain anonymous (Draper and Brown 2004). Students also like the use of class response systems because clickers can make formative assessment seem like a game show (Carnevale 2005; Martyn 2007).

While students like clickers used for formative assessment, they do not like them to be used for summative assessment (Kay and Knaack 2009). MacGeorge et al. (2007) did not find gender or ethnicity differences in the preferences for clickers, but Kay and Knaack (2009) found that men liked clickers more than women and that those who were not otherwise inclined to actively participate in class liked clickers. Ghosh and Renna (2009) reported that students in lower-level classes perceived greater benefits from the use of clickers to facilitate peer instruction than students in upper-level classes.

Fies and Marshall (2006, 106) reviewed 24 other studies and concluded that there is widespread agreement that classroom response systems "promote learning when coupled with appropriate pedagogical methodologies." However, most studies have focused on how clickers enhanced the learning environment as measured by surveys of student attitudes, impressions and preferences. Few looked at summative assessments of student learning. For example, Siau, Sheng and Nah (2006) used pretest and posttest surveys to show that clickers increased measured classroom interactivity after mid-semester, but they did not consider student learning.

There is much less hard evidence about the effects of clickers on student learning (West 2005). Surveys show that students *think* that they are learning more (Ghosh and Renna 2009; Cardoso 2010; Litzenberg 2010), but a survey of the early literature by Judson and Sawada (2002) found no significant correlation between the use of electronic response systems and actual student learning. They attributed this to an early emphasis on direct recall of traditional lecture material, and suggested that the more recent use of clickers to facilitate active learning as pioneered by Mazur (1997) was more promising.

Carnaghan and Webb (2007) found that students strongly favored use of the clickers and thought they learned more because they used clickers. However, Carnaghan and Webb concluded that students did not actually learn significantly more and did not view the course more favorably as a result of using the clickers. They attempted to have the same pedagogy in the experimental and control sections including displaying the same questions at the same points in the class so that their results would show only the effects of the clickers themselves and not a more active learning environment. Carnaghan and Webb found that students did somewhat better on examinations in classes where clickers were used, but only when the questions on the tests were like those had been asked in class using the clickers.

A review of literature by MacArthur and Jones (2008) concluded that reported gains in student learning were always associated with student collaboration. The two main approaches to student collaboration follow Dufresne et al. (1996) at the University of Massachusetts and Mazur (1997) at Harvard. Dufresne's "assessing to learn" (A2L) approach follows a think-pair-share-vote-discuss strategy (Beatty and Gerace 2009, 157). Mazur's peer instruction (PI) approach has students vote a second time in a think-vote-pair-share-vote sequence (MacArthur and Jones 2008, 190). Crouch and Mazur (2001) reported improved student learning using peer instruction in multiple courses and instructors over several years. The focus was on the benefits of peer instruction as compared to traditional lecture; clickers were used only to ask questions that facilitate active learning. The use of clickers for this purpose is in its infancy in economics compared to their use in physics (Elliott 2003; Maier and Simpkins 2008; Salemi 2008; Litzenberg 2010).

Students benefit from a more active learning environment (Mazur 1997; Weaver and Qi 2005), and clickers facilitate active learning. But West (2005) suggests that learning differences sometimes attributed to the use of clickers may actually be due to the shift from passive traditional lecture to more active learning. Martyn (2007) found no significant difference between classes using traditional discussion and classes using clickers. Miller, Ashar and Getz (2003) found that students were more attentive and more pleased with the learning experience when using clickers, but that students did not actually learn more as a result of using clickers.

Evidence on the relationship between clicker use and student learning has been limited and mixed. Kennedy and Cutts (2005) found that students who responded using clickers more frequently and more correctly to formative assessment questions did better on summative assessments. Pemberton, Borrego and Cohen (2006) found no significant difference in summative assessments between students who used clickers during a review time and those who did not use them, although students liked using the clickers and students who got higher clicker review scores did better on tests. Stowell and Nelson (2007) compared clickers to hand-raising and response cards; they found that clickers give a more accurate representation of student understanding as measured by a quiz given at the end of class, but found no evidence that clickers actually helped students to learn. Knapp and Desrochers (2009) and Lasry (2008) found that active learning methods helped students to learn, but that clickers were no better than other approaches to facilitating active learning, except that students preferred to use them. Morgan (2008) found no significant differences in student learning with clickers, although students liked using them. Morling, et al. (2008) reported modest exam performance improvements associated with using clickers to administer reading quizzes, but the benefit may have been from the reading quizzes rather than the use of the clickers to administer them.

Beuckman, Rebello and Zollman (2007) compared one group of students using PDAs with another group using clickers and found that the group using PDAs had higher course grades. They also found that students who responded more frequently to questions posed obtained higher course grades than those who participated less frequently. New software allows students to use their mobile phones instead of clickers both in class and in distance education (Stav et al. 2010). For example, polleverywhere.com facilitates using mobile phones as clickers through their web site. Using mobile phones means that students do not have to purchase clickers, but there are other fees for levels of service beyond anonymous polling of small classes.

Students need to attend class regularly to do well on the daily clicker questions. Many studies have reported that class attendance improves student performance (Schmidt 1983; Lumsden and Scott 1987; Romer 1993; and Marburger 2006). Krohn and O'Connor (2005) found that attendance improved overall course performance, but was not related to scores on individual examinations for intermediate macroeconomics students.

Evidence on the effect of study time on student performance has been mixed. Ballard and Johnson (2004) reported that study time is positively related to student performance. Others found study time was not related to student performance (Schmidt 1983; Lumsden and Scott 1987; and Gleason and Walstad 1988). Didia and Hasnat (1998) found study time to be negatively related to performance in the introductory finance course. Borg, Mason and Shapiro (1989) found study time to be positively related to performance for above average students and not significantly related for below average students as measured by ACT/SAT composite scores; across all students study time was not significantly related to performance.

Siegfried's 1979 survey article reported mixed evidence on the effect of gender on student performance in economics courses. The same inconclusive message has continued to the present. Some have found that men do better than women, especially on multiple choice tests (Lumsden and Scott 1987; Anderson, Benjamin, and Fuss 1994; Ballard and Johnson 2004; and Krohn and O'Connor 2005). Others have found no significant gender differences (Williams, Waldauer, and Duggal 1992; Lawson 1994; and Swope and Schmitt 2006).

Many studies have reported that students' math skills are important for success in economics courses. Some reported that students who had taken calculus had more success in economics (Anderson, Benjamin, and Fuss 1994; Durden and Ellis 1995; and Ballard and Johnson 2004). Saddler and Tai (2007) found that students who had taken more mathematics courses in high school did better in all their college science courses. Ely and Hittle (1990) found that the number and type of math courses taken in high school were not important, but that students' self-reported quality of college math courses and attitude toward math were important. Benedict and Hoag (2002) reported that students who have better math backgrounds also have less anxiety in their economics classes.

Ballard and Johnson (2004) used a ten question basic math skills quiz to predict success in Principles of Microeconomics. Schuhmann, McGoldrick and Burrus (2005) used a pre and post course math quiz to explain pre and post course economic literacy. Pozo and Stull (2006) found that requiring a math skills unit improved students' economics performance.

Cumulative GPA has often been found to be a key predictor of success (Park and Kerr 1990; Durden and Ellis 1995; Didia and Hasnat 1998; Ballard and Johnson 2004; and Krohn and O'Connor 2005). Grove, Wasserman and Grodner (2006) found that collegiate GPA was the best single measure of academic aptitude, but cautioned against using semester or cumulative GPA measures that include the economics course grade. Our cumulative GPA measure was observed at the beginning of the term in which Principles of Microeconomics was taken, so it avoids this problem.

Siegfried's early surveys reported heavy reliance on TUCE scores as dependent variables (Siegfried 1979; and Siegfried and Fels 1979). More recently there has been less uniformity in the choice of a dependent variable. The TUCE is still used by some (Gleason and Walstad 1998; and Dickie 2006). Schuhmann, McGoldrick and Burrus (2005) used selected TUCE questions. Schmidt (1983) used a test that combined some TUCE questions with others of his own. Some have used their own tests or portions of their tests, including the final exam (Lumsden and Scott 1987; Williams, Waldauer and Duggal 1992; Romer 1993; Krohn and O'Connor 2005; Marburger 2006; and Pozo and Stull (2006). Ballard and Johnson (2004) used the percentage of test questions answered correctly on all tests combined. Success has often been measured in recent years by the course grade or the course average used to assign course grades (Borg, Mason and Shapiro 1989; Ely and Hittle 1990; Anderson, Benjamin and Fuss 1994; Durden and Ellis 1995; Didia and Hasnat 1998; Borg and Stranahan 2002; and Krohn and O'Connor 2005). Park and Kerr (1990) used the probability of each course grade.

Data and Methodology

While we use clickers to collect data in classroom experiments, almost all our clicker questions are used to assess student knowledge of recently presented course content. Students are encouraged to interact in answering all of the questions, so there is no "cheating" by definition.

Students receive ¼ point of extra credit for each clicker question answered correctly; only questions that have correct answers count. This amounts to about 1 point per day out of about 1000 points for the semester. This modest amount of extra credit encourages students to consider their responses carefully without shifting their motivation from intrinsic to extrinsic. Also the clicker questions remain formative rather than summative assessments. In the predictive model our clicker variable is the percentage of questions answered correctly.

We could not use the course grade directly as the dependent variable, because it included one of our independent variables, namely student performance on the clicker questions. So we constructed a dependent variable we call "assessment percent," which removed the extra credit from the course grade. Our assessment percent variable is the percentage of test and quiz questions answered correctly throughout the semester. Summative tests and quizzes do not use the class response system.

We gathered data for four semesters of Principles of Microeconomics courses taught by the same instructor from spring 2009 through fall 2010. We used dummy variables for the different semesters. The total sample size was 129, but incomplete data for some students reduced the sample size to 104. We recorded student performance on the daily clicker questions, each weekly quiz and each unit test. Ballard and Johnson's (2004) basic math quiz was administered on the first day of class as a diagnostic tool. Students were told that the math quiz would identify those needing extra help with math skills, but it was not part of their grade. We used an in-class survey on the first day of class to collect data on gender, class, race, work hours, activity hours, study hours, whether the remedial math course had been required, whether a calculus course had been taken, whether a high school economics course or any prior college level economics courses had been taken, and whether Principles of Microeconomics was required for the student's major.

We accessed student records to find cumulative GPA at the beginning of the semester and ACT scores. Where students had SAT rather than ACT scores, the SAT scores were converted to ACT scores using concordances between ACT and SAT scores (Dorans 1999; ACT 1998). There were only a few first semester freshmen, so students without a prior college GPA were excluded from the sample. We used ordinary least squares regression to estimate the linear relationship between the independent predictor variables and the dependent variable assessment percent.

In order to answer clicker questions correctly students must do several things. Of course, they need to know the answer, or learn it from another student after the question is posed. But they also need to…own a clicker…register the clicker in the Blackboard course management system, which links their answers to their name in the grade book…remember to bring the clicker when they come to class…and be present in class when the questions are asked. So clicker percent could be measuring attendance among other things, and attendance has been shown to be an important predictor of student performance (Schmidt 1983; Lumsden and Scott 1987; Romer 1993; Krohn and O'Connor (2005); and Marburger 2006). So we constructed a separate variable we call "attendance percent" to control for this effect. This independent variable is the fraction of the days clickers were used that a student was present in class.

Results

Table 1 gives descriptive statistics. The average student correctly answered 72% of the daily formative clicker questions and 80% of the summative test and quiz questions. The average attendance on days clickers were used was 87%, and clickers were used almost every day. About two thirds of the students were male, and about half had completed a calculus course. About half of the students were sophomores, and almost all were Caucasian.

Table 2 shows the regression results including all of the dependent variables. According to the adjusted R^2, the variables in the full model explain 68.7% of the variation in assessment percent. The quantitative predictor variables were not highly correlated with each other; the highest Pearson r correlation was 0.64 between clicker percent and attendance percent.

We know that the adjusted R^2 reduces the artificial inflation of R^2 due to non-significant independent variables in a linear regression. However, we were interested in better estimating the contribution the most important predictors made to learning. So we arrived at a parsimonious model using partial F-tests to see whether or not a subset of the original predictor variables was sufficient for prediction. Starting with the full model, we deleted individual variables with p-values more than 0.1. Partial F-tests showed that the reduced model was not significantly worse at predicting assessment percent than the full model. The reduced model explains 70.3% of the variation in summative assessment.

Student performance on daily clicker questions was high in the short list of predictor variables. Indeed, it was second in significance only to ACT composite. Students who had been required to take a remedial math course did worse in Principles of Microeconomics, but other measures of math skills and ability that had proved to be important in the literature were not significant. Activity hours were slightly negatively correlated with assessment percent (Pearson r = -0.04), and were not significantly different from zero (p-value = 0.69). But after controlling for other variables, activity hours had a slightly positive and significant influence on assessment percent. Prior college GPA was also a significant predictor.

Being African or African American was positive and significant, but this may reflect some unusual things in the data. In the original sample there were eight African or African American students, but five of these eight needed to be omitted from the analysis due to incomplete data. This left us with three students, two of whom were excellent. So we suspect that our results concerning race were influenced by the fact that our students are so overwhelmingly Caucasian and that the missing data issues distorted the sample so that the few remaining African or African American students were disproportionately excellent.

Each of the following categories contained less than ten percent of the students: African or African American, Asian or Asian American, Hispanic, remedial math course completers, Issues in Economics completers, Principles of Macroeconomics completers and Principles of Microeconomics repeaters. So we checked to see if removing these small categories would change our results. Table 3 shows the regression results for the remaining variables. Daily clicker questions remained a significant predictor of summative assessment along with ACT composite and prior college GPA.

Starting with the full model without the small categories, we again deleted individual variables with p-values more than 0.1 to arrive at a more parsimonious model. Partial F-tests showed that this reduced model was not significantly worse at predicting assessment percent than the corresponding full model. The reduced model without the small categories still explains over half of the variation in summative assessment. Daily clicker questions, ACT composite and prior college GPA remained significant predictors of summative assessment.

Conclusions

Daily clicker questions are shown to be an important predictor of student performance in small Principles of Microeconomics classes after controlling for other variables that have been shown to be important in the literature. Students who did better in daily formative assessments also did better in subsequent summative assessments. Of course, if students are absent, they cannot answer the in-class questions. But attendance by itself was not a significant predictor of summative assessment, and the percent of clicker questions answered correctly was an important predictor even after controlling for attendance.

Because students are encouraged to interact in answering all of the clicker questions, one might expect too much uniformity in the answers for them to be significantly related to test and quiz scores. However, the percentage of daily formative clicker questions answered correctly remained a key predictor of summative assessment even after less significant predictors and small categories were removed. If students “get it” in class, they have it for the quizzes and tests, and “getting it” in class is more important than all other predictors except ACT composite.

The multiple choice clicker questions may predict summative assessment well, partly because tests are entirely multiple choice and quizzes are mostly multiple choice. Carnaghan and Webb (2007) found that students did better on tests when the questions on the test were like those asked using the clickers. Accordingly, we plan to change the summative assessments so that there are more free response questions and replicate the analysis.

Table 1: Descriptive Statistics

Variable	Percent in Category	Median	Mean	Standard Deviation
Assessment percent		0.81	0.80	0.11
Daily clicker percent		0.76	0.72	0.17
Attendance percent		0.89	0.87	0.12
ACT Composite		27.00	26.86	4.02
GPA at the beginning of the semester		3.37	3.30	0.58
Activity hours per week		6.00	7.93	7.29
Work hours per week		0.00	3.13	4.12
Study hours per week for all classes		15.00	17.23	9.42
Basic math quiz score (10 possible)		8.50	8.05	1.79
Male	65.38%			
Calculus completed	52.88%			
High school economics completed	47.12%			
Issues in Economics completed	3.85%			
Principles of Macroeconomics completed	9.62%			
Repeating Principles of Microeconomics	5.77%			
Remedial math course completed	6.73%			
Required for student's major	88.46%			
African or African American	2.88%			
Asian or Asian American	1.92%			
Caucasian	92.31%			
Hispanic	0.96%			
Freshman	12.50%			
Sophomore	52.88%			
Junior	24.04%			
Senior	10.58%			
Spring 2009	25.96%			
Fall 2009	27.88%			
Spring 2010	20.19%			
Fall 2010	25.96%			

Table 2: Results for the Full Model and the Reduced Model with All Variables

	Full Model			Reduced Model		
	Coefficient	t-statistic	p-value	Coefficient	t-statistic	p-value
Constant	0.07542	0.93	0.35	0.11604	2.06	0.04
ACT Composite	0.012204	5.06	0.00	0.014226	7.29	0.00
Daily clicker percent	0.17745	3.30	0.00	0.20066	4.97	0.00
Activity hours	0.002590	2.48	0.01	0.0034167	3.89	0.00
Remedial math course	-0.08593	-2.80	0.01	-0.09079	-3.47	0.00
GPA in prior semesters	0.04229	2.44	0.02	0.04074	2.96	0.00
African or African American	0.09809	1.98	0.05	0.14601	3.76	0.00
Hispanic	0.04133	0.55	0.59	0.04795	0.78	0.44
Asian or Asian American	-0.03530	-0.71	0.48	-0.02880	-0.66	0.51
Basic math quiz	0.006435	1.28	0.21			
High School Economics	0.01386	1.01	0.32			
Work hours	-0.001803	-1.00	0.32			
Principles of Macroeconomics	0.02130	0.80	0.42			
Male	0.01412	0.80	0.43			
Attendance percent	0.05734	0.74	0.46			
Study hours	0.0005041	0.64	0.52			
Calculus	-0.01093	-0.61	0.54			
Required for major	0.01292	0.60	0.55			
Repeating Principles of Microeconomics	0.01372	0.37	0.72			
Issues in Economics	0.00981	0.26	0.80			
Freshman	-0.01848	-0.80	0.43			
Junior	-0.00901	-0.52	0.61			
Senior	0.01158	0.44	0.67			
Spring 2009	-0.01375	-0.65	0.52			
Spring 2010	-0.02256	-1.04	0.30			
Fall 2010	-0.01407	-0.74	0.46			
	Full Model			Reduced Model		
Adjusted R^2	68.7%			70.3%		
F (p-value)	10.06 (0.00)			31.41 (0.00)		
n	104			104		
Partial F (p-value)				0.73 (0.77)		

Table 3: Results for the Full Model and the Reduced Model without Small Categories

	Full Model			Reduced Model		
	Coefficient	t-statistic	p-value	Coefficient	t-statistic	p-value
Constant	0.19670	2.06	0.04	0.25845	4.23	0.00
ACT Composite	0.010410	4.11	0.00	0.010408	5.04	0.00
Daily clicker percent	0.21039	3.13	0.00	0.19368	3.91	0.00
GPA in prior semesters	0.04843	2.57	0.01	0.03962	2.48	0.02
Freshman	-0.04179	-1.64	0.11			
Junior	-0.01268	-0.68	0.50			
Senior	0.02482	0.76	0.45			
Work hours	-0.002723	-1.36	0.18			
Male	0.02584	1.32	0.19			
Activity hours	0.001254	1.09	0.28			
Study hours	0.0005711	0.74	0.46			
Required	0.01172	0.53	0.60			
Calculus	-0.00509	-0.27	0.79			
High School Economics	0.00333	0.23	0.82			
Attendance percent	-0.00356	-0.04	0.97			
Basic math quiz	0.000179	0.03	0.98			
Spring 2009	-0.01773	-0.77	0.45			
Spring 2010	-0.01676	-0.65	0.52			
Fall 2010	-0.00891	-0.43	0.67			
	Full Model			Reduced Model		
Adjusted R^2	56.5%			52.6%		
F (p-value)	6.70 (0.00)			30.28 (0.00)		
n	80			80		
Partial F (p-value)				1.45 (0.15)		

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