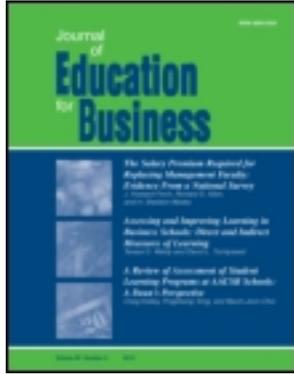


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Denise Stanley^a

^a California State University, Fullerton, Fullerton, California, USA

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Can Technology Improve Large Class Learning? The Case of an Upper-Division Business Core Class

Denise Stanley

California State University, Fullerton, Fullerton, California, USA

Larger classes are often associated with lower student achievement. The author tested the hypothesis that the introduction of personal response systems significantly improves scores in a 250-seat classroom, through the channels of improved attendance and engagement. She focused on how continuous participation with the technology could change learning results. The author found that overall attendance rose when the response system was introduced. Regression results show student exam performance during the semester with technology was improved significantly by I-Clicker points per session rather than attendance, while the reverse holds true regarding unannounced quizzes.

Keywords: academic performance, interactive technology, managerial economics

Traditional wisdom suggests larger classes mean lower student achievement rates or no difference in outcomes (Kokkelenberg, Dillon, & Christy, 2008). Reduced attendance rates and less student engagement are among the most frequent problems with the large room setting (Nelson & Hauck, 2008). Lab sections, breakout groups, online posting of lecture notes, and classroom response systems represent a few of the methods to make student learning in a large classroom more equal to that in a small one.

In this study I used regression techniques to determine if personal response systems significantly impact student outcomes in intermediate economics. Unlike previous studies treating the response system participation as a dichotomous effect, here I analyze how the continuous usage of the response systems affects student engagement and rapid learning as compared to attendance enhancements *per se*. I also differentiate whether the response systems impact surprise assessments in the same manner as planned tests.

I first review the literature and outline how response systems could impact learning. I present data on test scores and demographic backgrounds from students in managerial economics at a large public university setting. I find that the technology improves exam performance more through immediate learning gains rather than an attendance boost.

LITERATURE REVIEW

Personal response systems (e.g., I-Clickers) allow for immediate feedback to the instructor and student. They are hand-held devices in which students answer questions electronically in class. These devices could make students more interested in attending and focusing during class. Students are answering anonymously, which could bring in more involvement from less confident participants. However, the response systems have an opportunity cost; class minutes spent on technology training and clicking could have been spent on discussion, question-and-answer periods, or other activities.

Nearly all recent statistical analyses compare class sections with the response system against those without. Positive correlations between the response system usage and class grades, quizzes, or exams have been noted for marketing (Sprague & Dahl, 2011), psychology and education research methods (Bartsch & Murphy, 2011), earth science (Gray, Steer, McConnell, & Owens, 2010), biology (Caldwell, 2007), and operations management (Yourstone, Krave, & Albaum, 2008). Most studies also include student comments, or statistics, showing higher student attendance rates or enthusiasm. For instance, Eastman, Iyer, and Eastman (2011) found high rates of attention and positive attitudes toward the use of the interactive technology in a required marketing course. However, Matus, Summa, and Kuschke (2011) reported no significant gain for capstone business students using response systems, when compared to their peers in online and lecture sections.

The assistance of Dr. Morteza Rahmatian is greatly appreciated.

Correspondence should be addressed to Denise Stanley, California State University, Fullerton, Department of Economics, 800 N. State College Boulevard, Fullerton, CA 92834, USA. E-mail: dstanley@fullerton.edu

Bergstrom (2009) first outlined how to teach economics principles interactively using response systems. Salemi (2009) and Ghosh and Renna (2009) then demonstrated student enthusiasm as evidenced by multiple choice question response levels, higher attendance rates, and positive exit survey opinions. But Johnson and Robson (2008) found no significant difference in the grade distribution nor standardized exam scores in a required microeconomics principles class taught with and without response systems.

METHODS

Class Design

Economics 315 (managerial economics) is a required core course within the Bachelor of Arts in Business Administration at a large public university (California State University, Fullerton). The focus instructor lectures with PowerPoint slides and offers four closed-book exams, with the stated policy that the best three would be used for 90% of the student's final grade. The exams represent the general structure of the course (economic principles, production theory and costs, advanced market structure and failure). The best two of three required surprise in-class quizzes comprise 10% of student grades. Several surprise extra credit writings are used in final grading and provide additional evidence of general attendance trends. I added up the seven days in which student presence each semester would be noted for either unannounced quizzes or extra credit.

The instructor first started teaching in a large classroom (250 seats) in 2008 and agreed to analyze the response system technology effects in 2010, with the same class time, textbook, and assessments but I-Clickers in the fall. During the first week students practiced answering questions posted on the screen. They then had eight classes in which correct personal response rates formed 5% of their final grades, with less weight placed on quizzes. Each preannounced I-Clicker session involved five multiple-choice questions across a roughly 20-min section of class. This meant a reduction in the class time normally devoted to student questions.

Specification of the Links Between Section Choice, I-Clickers, and Performance

I work with a general model of student achievement, formed from the idea of the education production function (Maxwell & Lopus, 1995):

$$K = f(S, I, D, T, K_{t-1}) \quad (1)$$

where S = class size (fixed), I = instructor (fixed), D = student personal demographics and workload management, T = technology used in classroom (level of I-Clicker attendance and achievement), and K_{t-1} = knowledge brought to course.

I consider student learning outcomes K on planned exams and surprise quiz scores. The first measure offers an

indication of student overall learning (on a scale of 0–100) whereas the second provides an indication of more immediate understanding (on a scale of 0–10). The previous knowledge variables K_{t-1} are captured in the student's cumulative (presemester) grade point average (GPA) and previous grade in the prerequisite economic principles.

Data from a student survey provide information for the demographic and workload variables. These include student age, gender, distance from campus, whether the student was a first-generation college student, hours of work, semester credit load, and whether the student was taking the class section of his or her choice. I posited that older male students would perform better, as there has been evidence of a gender gap in economics (Anderson et al., 1994). Students whose parents did not attend college could be at a disadvantage in developing study habits and economic and financial literacy. A higher off-campus workload, as well as course load and commuting time, would reduce the time students have to study. Also, students at this campus do not know they are in a large class until the first day. If students end up in a suboptimal class time, their ability to manage class, family, and paid work responsibilities is diminished; attendance could fall. So I included a binary survey question asking if the observed section had been the student's top choice at registration.

I tested the hypotheses that the introduction of response systems significantly improves attendance and outcomes in the large-class setting. Initially I compared results across two semesters. But then I explored how the degree of involvement with the personal response systems affects outcomes by focusing on the fall semester data. I created two continuous variables (T): $T1$, number of response system preannounced session days attended (sessions registered); and $T2$, mean points earned across sessions (total correct responses registered / $T1$).

Granting an attendance point per day from the I-Clicker signal could increase grades in a large classroom because it gives students more news about class events. The issue of outsiders sitting in on a student's I-Clicker session is a clear problem since photo IDs are not checked for each session. But I did not observe a negative correlation between I-Clicker attendance and points and exam scores (i.e., if person A did well on the I-Clicker questions but unprepared student B takes the exam presumably an inverse effect would occur).

The attending, yet unmonitorable, students could continue to use class time on other activities (such as cell phone web browsing). So I chose an additional variable $T2$ (points earned per session) to gauge student involvement and active learning success. Eastman et al. (2011) considered student engagement as related to the attitude towards the class and attention paid during class. If students have negative perceptions of a large classroom, they may be less mentally engaged, experience less immediate learning, and demonstrate wrong (or blank) answers to response questions.

Initially I am concerned that unobserved factors affecting a student's involvement with response systems in the

large class could also affect learning outcomes. Unseen heterogeneous trends such as a student's home environment, computer usage, and social networking could mean a student who attended or engaged on session days may have an extra advantage on assessments. Thus I consider my outcome regressions below using both endogenous two-stage estimators on Equations 2 and 3 and standard ordinary least squares techniques with robust standard errors for Equation 3:

$$T_i = A + \sum_h b_h * X_{hi} + \omega \quad (2)$$

(Clicker technology level, where X includes all variables in Z and identifying variable)

$$K_i = a + \lambda * (T_i) + \sum_j [B_j * (Z_{ji})] + \varepsilon \quad (3)$$

where K_i = fall 2010 student average exam or quiz score, a = parameter to capture constant performance effect, A = parameter to capture constant technology level choices, λ = coefficient on I-Clicker technology degree (days or correct questions), b = coefficients on h demographic factors affecting participation, B = coefficients on j demographic factors affecting performance, T_i = degree of student participation in response technology (days or mean points), X_i = student D demographic and background knowledge K_{t-1} variables (including age), Z_i = student D demographic and background knowledge K_{t-1} variables, and ε, ω = the error terms where $\varepsilon \sim N(0, \sigma)$ $\omega \sim N(0, 1)$.

I kept the equations in level form because the 2.61 kernel density estimate of Equation 3 showed no particular left or right skewness. Additionally, 95% of the observations occurred within two standard deviations of the mean score.

RESULTS

Table 1 provides a casual analysis of the effects of the personal response system treatment. Fall students attended a significantly higher percentage of the seven unannounced tracked days when response systems were part of the pedagogy. And this attendance is positively correlated with exam scores (Pearson correlation coefficient = 0.26, p = 0.000075). Even though I-Clicker days were announced in advance, some students likely developed a more regular attendance pattern in general. The introduction of response technology in the fall appears to improve performance on some quizzes, but not necessarily the outcome on each individual exam. So at first view the results suggest a note of caution regarding response systems, as suggested in Johnson and Robson (2007).

Table 1 also includes explanatory variables for the I-Clicker technology used in the fall. Those attendance days cluster around 5–8 days and are strongly correlated with each student's total I-Clicker points earned across the semester. However, the student points per session exhibit a different near-normal pattern. The skewness and kurtosis for points

TABLE 1
Student Learning Outcomes Across
Semesters–Technology (Survey Respondents)

Item	Spring 2010 ($n = 229$)		Fall 2010 ($n = 205$)		t	df
	M	SD	M	SD		
Unannounced						
Quiz 1 ($n = 430$)	7.015	2.40	7.94	1.49	-4.738**	385
Quiz 2 ($n = 391$)	5.85	1.71	6.23	1.71	-2.203**	388
Quiz 3 ($n = 413$)	6.35	2.26	5.45	2.05	4.190**	410
Average best 2/3 quiz	7.06	1.74	7.24	1.39	-1.210	416
Announced						
Exam 1 ($n = 431$)	74.79	12.51	74.63	16.04	0.120	383
Exam 2 ($n = 425$)	67.37	13.61	68.02	16.51	-0.440	391
Exam 3 ($n = 431$)	76.61	10.88	64.53	13.62	10.090**	386
Exam 4 ($n = 272$)	63.82	11.22	68.23	0.98	-3.430**	269
Average best 3/4 exams	74.43	0.16	71.99	11.60	2.410**	385
Tracked unannounced attendance (7)	5.35	1.70	5.95	1.60	-4.190**	504
Announced I-Clicker: Attendance (of 8)	0	0	6.70	1.88		
Total points (of 40)			20.05	6.86		
Points per session (of 5)			2.98	0.05		

* $p < .05$. ** $p < .01$.

per session was .003 and $-.126$, respectively; the null hypothesis of normality was accepted, with a joint probability chi-square test statistic of 0.06. About one third of the students answered only 2–3 questions correct per session.

The group means in Table 2 demonstrate most of the students are men, and over one third of the sample were first-generation college students. They tended to be young students working at least part-time and carrying almost a full course load. Most commuted at least 30 min to class. More than 10% considered the enrolled (large) class to have not been their first choice. Students demonstrated a moderate overall GPA and generally earned a C grade in the prerequisite course. There are few significant differences across the semesters, except for the response system group having a smaller class load and less family college experience, which could have given the fall group a disadvantage.

First-stage results of Equation 2 factors determining I-Clicker attendance and points per session are listed in the Appendix. I used gender and age to identify the participation processes (Equation 2) apart from outcomes (Equation 3) in a IV Tobit estimation. The joint significance of the instruments was $F(1, 158) = 4.39$ for the case of points per session and 12.61 on attendance level, with the later suggesting an acceptable instrument. Note that higher GPA students attended sessions more frequently and demonstrated successful active learning. Male students attended less, while older students scored fewer points per session. Distance should affect attendance, but here it plays an insignificant role perhaps due to campus impaction in which admission standards vary by local or nonlocal area student residence. But I accept the hypothesis of exogeneity between I-Clicker attendance and exams and quizzes, Wald test: $\chi^2(1, N =$

TABLE 2
Student Demographics and Academic Background
Across Semesters/Technology

Item	Spring 2010 (n = 229)		Fall 2010 (n = 205)		t or χ^2	df
	M	SD	M	SD		
Age (years)	22.65	3.11	22.91	3.09	-0.84 (t)	415
Gender (male = 1, female = 0)	0.61	0.49	0.59	0.49	0.17 (χ^2)	1,424
Distance to campus (miles)	16.06	12.37	15.07	9.66	0.91 (t)	403
Hours work (hr.)	18.94	12.48	19.23	13.47	-0.22 (t)	403
Enrolled credits (units)	13.20	2.60	12.73	2.62	1.82* (t)	411
Did not want section (yes = 1, no = 0)	0.09	0.29	0.14	0.35	3.17* (χ^2)	1,432
First-generation college student (yes = 1, no = 0)	0.24	0.43	0.35	0.48	6.18** (χ^2)	1,407
College grade point average (0-4)	3.10	1.75	3.25	2.99	-0.62 (t)	299
Grade in college algebra (0-4)	3.32	0.66	3.26	0.78	0.84 (t)	349
Grade in college calculus (0-4)	2.99	0.76	2.95	0.81	0.53 (t)	371
Grade in college principles (0-4)	2.87	0.71	2.97	0.75	-1.37 (t)	384

*p < .05. **p < .01.

172) = 0.18, Hausman test: $F(1, 161) = 0.17$; Wald test: $\chi^2(1, N = 168) = 1.22$, $F(1, 157) = 0.01$, respectively.

Tables 3 and 4 (using the ordinary least squares results) outline the processes affecting exam and quiz scores during the fall 2010 semester. The large *F* statistics demonstrate the overall significance of the regressions, with background knowledge being most important. Overall GPA and grades in principles increase scores by at least a half letter grade on exams. No gender gap appeared in the exam or quiz results, which follows the results of Marcal, Hennessy, Curren, and Roberts (2005) regarding marketing.

The results suggest a moderate, significant, effect of the response systems technology on student assessments. I turn first to attendance days in Table 3. I expect the technology to impact quiz results to a greater degree since they fall soon after the response system exercise. However quizzes are surprise assessments so students may not have all notes handy, and the coefficient on response system attendance is barely significant in Table 3. There are 100 points possible on each exam, and attending all eight possible I-Clicker days can raise the score on the margin by over a half grade (six points) compared to a student with no attendance on those days, with all other variables at their means.

And there is a modest score boost for low- and high-achieving students. I considered student characteristics at the actual values but then placed observations in a low (2.0) or high (4.0) GPA regime. The predicted score for low GPA-

TABLE 3
Fall I-Clicker Attendance Effects (n = 172)

Item	Exam scores (of 100 points)	Quiz scores (of 10 points)
Constant	24.55 (9.30)**	2.13 (1.18)*
Attendance	0.76 (0.44)**	0.11 (0.06)*
Age	0.01 (0.27)	0.03 (0.03)
Gender	-0.59 (1.44)	-0.21 (0.19)
Distance to campus	0.001 (0.74)	-0.003 (0.01)
Hours work	-0.07 (0.05)	-0.006 (0.007)
Enrolled credits	0.04 (0.28)	0.06 (0.04)
Didn't want section	-1.58 (2.45)	0.14 (0.25)
First-generation college student	-0.35 (1.47)	0.11 (0.19)
College grade point average	9.68 (1.44)**	0.71 (0.18)**
Grade in college principles	4.98 (0.93)**	0.37 (0.11)**
	$F(10, 161) = 24.49**$ $R^2 = .52$	$F(10, 161) = 7.63**$ $R^2 = .28$

*p < .10, **p < .05. Data in parentheses represents robust standard errors for associated coefficients.

type students increased from 57.05 to 64 for attending the eight response system sessions, while that of the high GPA-type students rose from 76.40 to 83.35, after controlling for background factors.

Table 4 demonstrates that active learning and engagement during the session matters. If a student answers all five questions correctly every session, exam scores rise significantly by nearly two letter grades (18 points). I predict that a student, with mean GPA and demographic characteristics, answering just one question correct per session would earn 64.50 points while one answering all five questions correct on average earns 79 points. Thus engagement during class

TABLE 4
Fall I-Clicker Performance Effects (n = 172)

Item	Exam scores (of 100 points)	Quiz scores (of 10 points)
Constant	22.23(10.39)**	2.29 (1.24)*
Points per session	3.64(1.40)**	0.22 (0.20)
Age	0.01(0.30)	0.03 (0.03)
Gender	-0.99(1.46)	-0.31 (0.19)*
Distance to campus	-0.004(0.07)	-0.003 (0.01)
Hours work	-0.10(0.05)*	-0.008 (0.007)
Enrolled credits	-0.006(0.31)	0.05 (0.04)
Didn't want section	0.17(2.56)	0.27 (0.26)
First-generation college student	0.25(1.50)	0.15 (0.20)
College grade point average	4.46(1.00)**	0.76 (0.18)**
Grade in college principles	4.46(0.99)**	0.32 (0.12)**
	$F(10, 161) = 26.31**$ $R^2 = .53$	$F(10, 161) = 6.98**$ $R^2 = .27$

* p < .10, **p < .05. Data in parentheses represents robust standard errors for associated coefficients.

appears to have a greater impact on student exams than does mere attendance during announced sessions. There are 10 points possible on each surprise quiz, and the effect of each correct response system question is insignificant in Table 4. Student GPA and prerequisite knowledge drive the results, and in this specification a small reverse gender bias appears.

DISCUSSION

The results suggest attendance and active learning go together to increase student performance. But more successful response system sessions increase exam scores the most. It is possible that those who were the most active in answering questions successfully were those who most quickly learned with technology. Whether this relates to student learning styles and speed of material acquisition—or whether it relates to the instructor's incentive grading technique to emphasize points—remains to be explored. But this suggests that adequate time for technology training—perhaps in an ungraded prerequisite session before the semester—is essential to keep all students on par.

The lack of correlation between response system attendance, but not achievement, and quiz results remains puzzling. This means that if a student attends an I-Clicker day, but answers no question correctly, he or she may still have some quiz score benefit from the technology. This class presence may be providing students with networking opportunities and medium-term knowledge. Concept learning may not exist across a week period or in a surprise setting; but students can integrate their active learning sessions with deeper studying for an announced exam even a month later. This suggests instructors should provide follow-up tools, such as question and answer handouts after each session.

CONCLUSION

Large-sized classrooms will continue at many universities. This experiment expands the research around large-class pedagogies by offering a method to analyze the continuous treatment effects of response technologies on student learning. The treatment involved a moderate number of response system multiple-choice questions appropriate for the problem-solving emphasis of the class with only a small sacrifice of class time.

Several trends emerge. First, the personal response systems tend to boost unannounced class attendance overall in both semesters, and this raises scores. But the direct effect of the response systems across the semesters appears mixed. Second, the degree of technology usage matters. I found that the fall 2010 semester students who participated with full I-Clicker attendance received almost a half grade higher on average exam scores than students without such attendance. And points earned per session significantly raised exam scores. Interestingly, higher scores on quizzes

are significantly related more to session attendance than performance.

Overall I found the greatest benefits to student learning—and semester grades—come through how the response technology boosts overall attendance and promotes active engagement. I stress the need to encourage participation through incentives such as rewarding correct responses in addition to actual attendance. Such a scheme also could discourage cheating in which a friend merely shows up and clicks for a registered student. Other surprise assessments across the semester are also important.

Limitations of the study include its focus on a single-sized room for 250 students. Whether personal response systems can boost attendance and learning in even larger rooms (500 students) or smaller rooms (40 students) remains unclear. In addition, I have not explored learning trends across different assessment formats and response system vendors. The instructor relied on in-class multiple choice questions, and student work on other problem-solving exercises (graphing, mathematical calculations) with response systems could show a wider variation of outcomes.

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APPENDIX TABLES

TABLE A1
First-Stage Results on I-Clicker Attendance

Item	Coefficient	t
Constant	4.62 (1.12)**	3.85
Age	0.013 (0.03)	0.46
Gender	-0.80 (0.22)**	-3.65
Distance to campus	0.004 (0.01)	-0.02
Hours work	-0.009 (0.007)	-1.29
Enrolled credits	-0.02 (0.04)	-0.40
Didn't want section	0.006 (0.41)	0.99
First-generation college	-0.12 (0.24)	-0.50
College grade point average	1.14 (0.28)**	4.03
Grade in college principles	-0.21 (0.19)	0.02

Wald $\chi^2(9) = 259.32, n = 172, F(9, 163) = 4.23^{**}$.
 * $p < .10$, ** $p < .05$. Data in parentheses represents robust standard errors for associated coefficients.

TABLE A2
First-Stage Results on I-Clicker Points per Session

Item	Coefficient	t
Constant	2.25 (0.36)**	6.16
Age	-0.02 (0.009)**	-2.15
Gender	0.003 (0.07)	0.04
Distance to campus	0.002 (0.004)	0.05
Hours work	0.005 (0.003)**	2.04
Enrolled credits	-0.004 (0.01)	-0.33
Didn't want section	-0.16 (0.10)	-1.51
First-generation college	-0.07 (0.07)	-1.04
College grade point average	0.30 (0.09)**	3.31
Grade in college principles	0.09 (0.06)	1.47

Wald $\chi^2(9) = 293.91, n = 172, F(9, 163) = 3.60^{**}$.
 * $p < .10$, ** $p < .05$. Data in parentheses represents robust standard errors for associated coefficients.