The Effectiveness of Interactive Online Exercises across Delivery Format

By
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ABSTRACT

Colleges and Universities are increasingly experimenting with the online delivery format as a way to meet the growing demand from non-traditional students for increased educational opportunities outside the traditional classroom. At the same time instructors are increasingly integrating online homework, quizzes, and discussion boards into their instructional materials. These online activities seek to promote learning by engaging students outside the traditional classroom lecture. This study evaluates the effectiveness of online activities controlling for delivery format. The data are from a Principles of Microeconomics class taught in three different delivery formats: traditional lecture, fully online (no in class meetings), or blended (combination of online lecture and in-class discussion. Overall the empirical estimates are consistent with our hypothesis that participation interactive learning exercises have a positive effect on exam score at a statistically significant level.

For Presentation at the American Economic Association, Annual Meetings, San Diego CA,

Session: The Effects of Online Economics Courses on Student Learning (I2)

Jan 06, 2013 1:00 pm, Manchester Grand Hyatt, Randle B

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I. INTRODUCTION

In Fall 2011 our Department, which is in a large Northeastern public university, offered a Principles of Microeconomics course in 3 formats – online, blended, and traditional lecture, under the supervision of one faculty member. The online materials for all sections consisted of interactive computer exercises, and online lectures. These instructional materials were developed and piloted in a small classroom environment of approximately 20+ students during the past two years. Students self-selected into 1 of 3 formats: traditional lecture (2 ½ hour meeting weekly with the supervising instructor), fully online (no in class meetings), or blended (1 ¼ hour meeting weekly with a first-year teaching assistant). The course enrolled 94 students completed the course: 26 in the traditional lecture section, 52 in the blended section and 16 in the online section. Data was collected (with the University's Institutional Review Board approval) on student performance, and student characteristics.

For all sections there were 11 online lectures consisting of a PowerPoint presentation for each chapter. For all students the PowerPoint lectures were made in available in 4 formats. One format was a flash version with audio overlays, closed captioning for most slides, and hyperlinks throughout that enable the user the interactive capability of self- directing their review of the lecture presentation. In the second format the flash version was converted to MP4 format and made available on YouTube so students could listen/watch from mobile devices. In the third format, the PowerPoint was made available in the PowerPoint outline format for the student to printout and annotate as they listened/watched the lecture. Finally, in the fourth format, the instructor taped a live presentation of the PowerPoint slides in a production studio. The videos were streamed, closed captioned and are each 30+ minutes in length. The lectures were made available to all sections. The students in the traditional lecture also received the PowerPoint slide s in a live lecture presentation.

II. DESCRIPTION OF INTERACTIVE COMPUTER EXERCISES

Four types of computer exercises were used: online discussion board, a quick 5-10 multiple choice quiz, 10-20 problems in Aplia, and self-evaluation multiple-choice review. For each lecture students were advised to complete the multiple choice quiz first and use the results as a signal for concepts needing review before beginning the exercises in Aplia. In the discussion board students were encouraged to post and answer questions of clarification about the concepts in the lecture and homework assignment. In the week before each hourly exam students were encouraged to use the final set of self-evaluation exercises as a diagnostic tool to identify topics needing more work.

Online Discussion

Weekly discussion and class Q/A is conducted in a Face book group for each section with

students added as group members (not as friends). A discussion thread is initiated each week and a portion of the student grade is based on weekly contributions to the thread. The contributions could be in the form of posing a course related question, responding to a posted question, posting a link to relevant material, or commenting on the linked material. The mobile App feature of Face book facilitates a 24/7 lively and productive discussion, and helps create a shared community experience (helpful assistance, thoughtful exchange of viewpoints) for the participants. The range of learning experience for this activity potentially spans all 6 levels of the Bloom taxonomy.

Across all sections 67% of the students posted at least once, and participation was highest in the traditional section 77%, followed by 69% in the online section and 62% in the blended section. Data on the student average number of posts per week for students that posted is reported in the table below. The students in the blended delivery format utilized the exercise the least with an average of 1.4 posts for students that posted. In this section students meet weekly for in-class discussion led by a teaching assistant. The students in the traditional section utilized the exercise the most with an average of 4 posts per student that posted. These students perhaps have the best sense of participating in a learning community.

	Module Averages For Students That Posted				
Section Type	Posts	Posts with Substantial Content	Posts with Links	Posts that ask Questions	Posts with Answers
ALL	2.4	2.0	1.1	2.0	1.5
Blended	1.4	1.3	.	1.6	1.1
Traditional	4.0	3.3	1.1	2.1	2.4
Online	2.4	2.1	1.0	2.0	1.5

Weekly Quiz

The weekly quiz has 5 to 10 multiple choice questions that test remembering and understanding (the first two levels of the Bloom taxonomy) of key concepts and terms in the lecture/module. It is recommended to students that they complete the quiz after review of the assignment in the textbook and the online lecture and before beginning the Aplia homework exercises. The quiz is not timed, it may be taken twice, and the display of responses for each question is randomized for the second attempt.

Data on student usage is reported in the table below. On average over the 10 quizzes 10% of the students scored 100 on their first attempt, and the remaining 90% scored on average 55. Almost everyone scored 100 on their 2nd attempt, as the questions on the two attempts are identical and the highest score was counted toward the final grade. The average time spent on the quiz exercise was 24 minutes and this was fairly constant throughout the semester and across students. (The LMS system records time spent on each attempt.) The intent of the exercise is to

give students a measure of their level understanding before beginning the graded homework assignment in Aplia.

	Attempt #1		Average Time Spent on Quiz (minutes)
Quiz #	% with Score =100	Avg if <100	
2	17%	57	25
3	12%	63	35
4	20%	62	14
5	8%	51	32
6	7%	54	23
7	3%	51	27
8	5%	53	24
9	16%	58	24
10	5%	45	15
11	10%	55	17
Average	10%	55	24
S.D.	5.8%	5.4	6.8

Aplia Homework

Aplia is an online service used for weekly homework assignments. Aplia has two formats for the problems: grade it now (GIN) where students have three attempts to choose the correct answer, with hints to guide the student to the correct response, and graded at deadline (GAD). Each assignment has 20 problems, half of the problems are GIN, and the other half has similar problems that are GAD. The former are weighted 90% and the latter 10%. The uneven weight distribution is chosen for reasons of student preference and to incentivize students to use the self-review feature of the GIN problems. The problems require the student to apply the economic concepts of the lecture to analyze hypothetical situations (as such the homework addresses the application and analysis levels, the third and fourth levels, of Bloom's taxonomy).

The GIN problems are used as practice to prepare the student for the problems in the GAD section. The level of difficulty of the problems in each section is similar. Aplia describes the pedagogy of joint use of GIN and GAD deadline problems in the following way: In every topic, we have two parallel problem sets. We suggest that you assign one in practice mode, which gives students immediate feedback about whether their answer is correct, together with an explanation of the reasoning behind this answer. Assign the other in graded mode, so no answers or explanations are revealed until after answers have been submitted for a grade.... The practice set helps weaker students prepare for the graded set and gives them a no-risk setting for getting started. Aplia gives you the option to assign everything in practice mode, but experience clearly demonstrates that most students, especially the students who most need to put in some extra effort, won't do optional problems unless they are preparation for graded problems with a looming deadline (http://www.aplia.com/community/articles/Summer05_getting_most_out_of_aplia.jsp).

Data on student usage is reported in the table below. Over the 10 homework assignments the mean score on the GIN problems (84) was 17 points above the mean score on the GAD problems (67). We speculate that the large weight differential (90%) favoring the GIN problems relative to the GAD problems (10%) and the potential problem of just looking clicking thru to get the answer for the GIN problems, are explanatory factors. A t-test of the difference in the mean score of 84 on GIN and 67 on GAD was conducted, and the means are significantly different at the 1% level. In the section on learning outcomes we provide more evidence on this.

Module/Lecture #	GIN Mean	GAD Mean	Difference
2	86	71	15
3	83	75	9
4	81	68	12
5	83	79	5
6	84	63	21
7	75	50	24
8	82	48	34
9	91	69	22
10	85	65	21
11	84	78	6
Overall Mean	84	67	17

Self-evaluation Exercises

There are 3 hourly exams, each is administered approximately every four lectures/modules. Two self-evaluation exercises: a practice exam, and a pop-quiz; are made available prior to each hourly exam. The practice exam is similar to the hourly exam; it has 30 multiple-choice questions and a 60-minute time limit. It can be taken several times, but the questions are identical in each attempt. The pop-quiz has 5 questions, and a 10-minute time limit. The questions are randomly pulled from a stratified pool of 300 multiple-choice questions, and the quiz can be taken unlimited times.

Data on student usage of the self-evaluation Practice Exam is reported in the table below. Though the average score on the first attempt for all three-practice exams was below 65, the average on the second attempt was above 70. (The questions are identical on both attempts.) Over the semester the trend is for the average score on each attempt to rise and the average time spent on the exercise to decrease.

	Average for Practice Exam #		
ATTEMPTS:	1	2	3
1st Attempt Score	56	63	64
1st Attempt Time (mins.)	24	25	17
2st Attempt Score	72	81	82
2nd Attempt Time (mins.)	22	15	11
Average Total Time on All Attempts (mins.)	60	43	26

Data on student usage of the pop-quiz is reported in the table below. Approximately 65% of the students participated in this exercise and approximately 60 minutes was spent on this activity per exam. In contrast to the practice exam, over the semester the trend is for average time spent to rise. (In a survey of student opinion of the relative effectiveness of the computer exercises, the pop-quiz was the hands down favorite.)

	POP QUIZ NUMBER		
	1	2	3
% Participating	65%	64%	68%
Average Number of Attempts	13	20	16
Average Minutes Spent	46	58	73

III. THE DATA

Descriptive Statistics for the sample are shown in the table below. Approximately 30% of the students self-selected into the traditional delivery format, approximately 55% selected the blended format and approximately 15% selected the online format. The class rank of the students was predominately 50% sophomores, 20% freshman and 20% juniors and seniors. The student majors were comprised of 55% economics or business, and 20% math or sciences. Fifty percent of the students held jobs and worked on average 12.75 hours a week. The average Math SAT score is 583, and Verbal is 535. Average GPA entering the course was 3.08 and 42% of the student were female.

Descriptive Statistics of Sample

Variable	N	Mean	Std Dev	Min	Max
Traditional	94	0.28	0.45	0	1
Blended	94	0.55	0.5	0	1
Online	94	0.17	0.38	0	1
Freshman	94	0.2	0.4	0	1
Sophomore	94	0.48	0.5	0	1
Junior	94	0.16	0.37	0	1
Senior	94	0.05	0.23	0	1
Not Set	94	0.1	0.3	0	1
Econ, Bus. Major	78	0.55	0.5	0	1
Math, Sci. Major	78	0.21	0.41	0	1
Have Job?	75	0.51	0.5	0	1
Weekly Hours Wkd	75	12.75	16.67	0	60
Math SAT	77	583.38	76.98	420	800
Verbal SAT	77	534.55	91.59	340	730
GPA at beginning	71	3.08	0.57	1.93	4.14
Female	78	0.42	0.5	0	1

The means for the three hourly exams, and a cumulative final (exam 04) are reported in the table below. For the full sample (bottom row of table) the mean is 67.46. The mean for the Blended format is the highest at 71.02, and the mean for the Traditional delivery format is the lowest at 61.23. The large difference raises a concern for sample selection bias. To address this issue we create a panel based on the 3 hourly exams resulting in a panel of 148 usable observations. The econometric approach is explained in the next section, and estimation results are presented in the following section.

	Full Sample		Traditional		Blended		Online	
Variable	Mean	N	Mean	N	Mean	N	Mean	N
EXAM01	74.05	90	71.29	24	76.8	50	69.57	16
EXAM02	67.73	91	64.65	25	69.26	51	67.69	15
EXAM03	73.25	89	71.23	25	75.24	51	69.32	13
EXAM04	67.46	88	61.23	25	71.02	50	65.74	13

III. MEASURING EFFECT ON LEARNING OUTCOMES

We are interested in whether participation in the online discussion board affected student exam scores. A potential econometric problem that arises in data like ours is bias from unobserved student characteristics and selection bias. One approach to this econometric problem is to arrange the data as a panel of the student's score on several exams. Following Marburger, (2001, 2005); and Chen and Fang (2008a, 2008b) we associated a measure of learning outcome

with measures of participation in the various learning activities. Using this method, we create a panel based on each of the three hourly exams and the usage measures for participation in the learning activities that correspond to each of the exams.

Following (Cameron 2010) and Sanca (2010) the panel data can be modeled as:

1. $y_{it} = \beta_1 x_{1it} + \beta_2 x_{2it} + \varepsilon_{it}$, where i = 1,2,…N ; t = 1,2, ….T.

1.

N is the total number of students, T is the total number of exams. The dependent variable y_{it} is exam score, where i is the i^{th} student, t is the t^{th} exam. x_{1i} is academic input; x_{2i} is the time invariant student characteristics; and $\square_i$ is the idiosyncratic error term. For academic input we use variables that measure the usage of interactive exercises. For student characteristics we use variables that measure academic achievement and demographic characteristics.

If the variable in x_2 is measured with error (i.e. it omits unobserved variables such as motivation, hour spent studying etc.) then the OLS estimates will not be unbiased. Let αi be the random individual-specific effects of the excluded variables. An approach to get unbiased estimates is to assume that the effects of the omitted variables are fixed for the individual, correlated with the individual's observed characteristics, and independent of the idiosyncratic error term. The αi are the random individual-specific effects, and η_{it} is the idiosyncratic error term. The resulting compound error term is written as: $\varepsilon_{it} = \alpha i + \eta_{it.}$ This is the "fixed effects" model and equation (1) then becomes:

(2) yit $= \beta_1 x_{1it} + \beta_2 x_{2it} + \alpha_i + \eta_{it}$.

We then estimate OLS on the mean difference transformed data:

(3) $yit - y_i = \beta_2 (x_{1it} - \bar{x}_{1i}) + (\eta_{it} - \bar{\eta}_i)$

The transformation eliminates the α_i but it also eliminates the time invariant characteristics, such as academic achievement, because they are constant across the question responses for each individual.

A limitation of the fixed effects model is that the mean difference transformation, which eliminates the α_i also eliminates the other time invariant characteristics, such as GPA, because they are constant across the question responses for each individual. The random effects model makes the stronger assumption that the unobserved effects uncorrelated with the regressor and permits the estimation of parameters for the time invariant variables.

IV. RESULTS AND DISCUSSION

For ease of discussion the estimation results pertaining only to the learning activities reported in the below partial table of results. A full table, including estimation results for the variables measuring student academic characteristics, is reported in the Appendix,

	OLS	Fixed Effects	Random Effects
	Exam score	Exam score	Exam score
Number of posts	1.044	1.805*	1.132+
	-1.57	-2.26	-1.74
Number of links	-2.684	-0.676	-1.744
	(-1.57)	(-0.34)	(-1.03)
Number of questions	-1.652	-2.889*	-1.87+
	(-1.66)	(-2.43)	(-1.92)
Number of answers	-0.898	-2.368*	-1.146
	(-1.09)	(-2.33)	(-1.42)
Time On Weekly Quizzes	-0.144	-1.965	-0.508
	(-0.08)	(-1.03)	(-0.31)
Change In Quiz Score	-0.148***	-0.141**	-0.149***
	(-3.43)	(-2.69)	(-3.53)
Grade It Now Score	0.134	0.0906	0.107
	-0.96	-0.52	-0.78
Graded at Deadline Score	0.183**	0.197**	0.190***
	-3.36	-3.19	-3.68
Practice Exam Score	0.00142	-0.0315	-0.0057
	-0.05	(-0.84)	(-0.19)
time on Pop-quizzes	0.0232	0.0541	0.033
	-0.33	-0.54	-0.44
attempts of Pop-quizzes	-6.263	-10.44+	-6.514
	(-1.11)	(-1.72)	(-1.23)
Student Academic Characteristics Reported in Appendix Table			
Constant	29.32*	62.22***	30.15*
	-2.19	-4.53	-2.08
Observations	148	148	148
R Sq	0.6171	0.3309	0.6213
F	8.69	2.59	
Prob > F	0.0000	0.0074	
Wald chi2			133.29
Prob> chi2			0.0000
t statistics in parentheses	+ $p < 0.10$ * p < 0.05, ** p < 0.01, *** p < 0.001		

Comparison of Models

The goodness of fit measures for the three models: OLS, Fixed Effects, and Random Effects; are reported in the bottom rows of the Table. Comparing OLS and Fixed Effects, for each model the calculated Prob value for F test of the null hypothesis that the estimated coefficients are not significantly different from zero, is rejected at the 0.01 level.

Separate tests are conducted to compare the goodness of fit of the OLS model to the fixed effects and the random effects model. The calculated value of the F test of whether there are fixed effects, (F test that all $\alpha_i = 0$), is 2.42 and is significant at the 0.001 level. Therefore we can reject the null hypothesis that there are no fixed effects.

For the random effects model the calculated value for the Breusch and Pagan Lagrangian multiplier (LM) test for random effects, is 3.41, which is significant at the 0.05 level. This LM test is for whether the variation of the individual specific effects is sufficiently large to reject the null hypothesis of no individual specific effects. Based on the calculated value of the LM statistic we can reject the OLS model in favor of the Random Effects model.

The Hausman test statistic for whether the estimated coefficients in the fixed and random effects models are different is 6.00 and the Prob >chi2 is 0.7998 meaning the fixed effects and random effects models are not different enough to reject the null hypothesis of no systematic difference. Based on these test results we can reject the OLS model in favor of the Fixed and Random Effects models, but we cannot reject the null hypothesis of no significant difference between the Fixed and Random Effects models.

Estimated Coefficients: Online Discussion

Comparison of the coefficients between the fixed and random effects shows the results are fairly robust to either specification. The coefficient for number of posts is positive and statistically significant at the 0.05 level in the fixed effects model. In the random effects model the coefficient is slightly smaller numerically, and the significance level falls to 0.10. These results imply participation in the discussion board has a positive impact on grade performance.

The coefficient for number of questions is negative and statistically significant at the 0.05 level in the fixed effects model. In the random effects model the coefficient is slightly smaller in absolute value, and the significance level falls to 0.10. These results imply that the students with questions have lower exam performance. An interpretation is that the answers were insufficient to improve the student's grade performance.

The coefficient for number of answers is negative and statistically significant at the 0.05 level in the fixed effects model. In the random effects model the coefficient is slightly smaller in absolute value, and is insignificance level at the 0.10. The negative coefficient is inconsistent with the expectation that students answering questions would be better prepared for exam questions than other students. The negative coefficient is consistent with an expectation that students use the discussion board for more social conversation that otherwise. However the

support for this interpretation is not supported by the insignificant result in the random effects model.

Estimated Coefficients: Graded Multiple Choice Homework: Weekly Quiz

For the weekly quiz two usage measures are employed, one measuring time spent, the other measuring change in score between the first and second attempt. The variable Time on Weekly Quizzes, which is total minutes spent on the quiz attempts for the quizzes before each hourly exam, is insignificant at the 10% level in both the fixed and random effects models. The coefficient for Change In Quiz Score, which is the change in the score between the first and second attempt is negative and significant at the 1% level in both models. In the earlier discussion of this exercise it was reported that only 10% scored a perfect 100 on their first of the two attempts. The negative sign for the estimated coefficient suggests that students who had the greatest improvement in score did so without learning the material.

Estimated Coefficients: Graded Multiple Choice Homework: Aplia

For the multiple-choice homework in Aplia, the usage measures are the score on the Grade It Now problems, and the Graded at Deadline problems. The estimated coefficient for the Grade It Now problems score is statistically insignificant in both models. However, the estimated coefficient for the Graded at Deadline problems is positive and statistically significant at the 5% level in both models. Recall from our earlier discussion, the motivation for the use of GIN problems was to provide guidance to the less sure students in a no-risk setting. The expected pay-off is that success on the GIN problems would translate into benefits on the high stakes exams. The estimated coefficients support the interpretation that the performance on the relatively higher stakes GAD problems are a better predictor of performance on the high stakes course exams. An implication is that increasing the weight for the GAD and reducing the weight for GIN problems would better align the incentives with the goal of improving learning outcomes.

Estimated Coefficients: Self-evaluation Exercises

The two self-evaluation exercises are a practice exam and a pop-quiz. As described earlier, the practice exam is 30 questions and can be taken several times but the questions are the same for each attempt. For the practice two usage measures are employed, one measuring the score and the other measuring time spent. To measure the score we created the variable Practice Exam Score, which is defined as the interaction of the score on the first attempt and an a indicator variable equal to one if the student took the practice exam, zero otherwise The other measure is Time Spent on Practice Exam. The estimated coefficients for Practice Exam Score are insignificant at the 10% level in both models, but the estimated coefficients for Time Spent of Practice Exam are positive and statistically significant at the 10% level in both models. This result suggests that studying helps.

For the 10-minute pop-quiz two usage measures are used: Time on Pop-quizzes, which is total minutes spent on the pop-quiz activity before each hourly exam, and Attempts of Pop-quizzes, which is number of attempts. The estimated coefficients for both measures are statistically insignificant at the 10% level, with one exception – Attempts of Pop-quizzes is statistically

insignificant at the 10% level for the fixed effects model. These results suggest that the no-risk practice exams were somewhat useful for students as they prepared for their high stakes exams.

V. SUMMARY

The authors investigate the effectiveness of three types of exercises: (1) graded participation in an online discussion board, (2) graded multiple-choice graded homework, and (3) ungraded self-evaluation multiple choice practice exams/pop quizzes. Effectiveness was measured by learning achievement on multiple-choice exams. Student participation in the discussion board was reported to have a positive and statistically significant effect on learning outcomes. The coefficient for graded multiple-choice homework was statistically significant if for relatively high stakes graded at deadline problems, and statistically insignificant for no-risk homework problems. For the self-evaluation exercises, the coefficient of Time spent on Practice Exam was positive and statistically significant, but the coefficients for usage measures of self-evaluation pop-quizzes were not. Students, however, rated these pop- quizzes, as the most effective learning exercise.

The exercises were administered across three sections of different delivery formats (traditional, blended, and online). However in our estimation results the indicator variable for influence of delivery format on exam score was not statistically significant at the 0.10 level.

Overall the empirical estimates are consistent with our hypothesis that participation interactive learning exercises have a positive effect on exam score at a statistically significant level.

Additionally it is to be noted that discussion threads and using the message tool are of great help for moderating discussions and keeping track of students. A discussion thread allows the instructor to have the posts easily grouped and allows easy access to review and evaluate student contributions to the discussion topic. The message posting facility organizes and displays private messages for easy review. Our anecdotal evidence suggested significant peer-to-peer learning. This observation is confirmed by the estimated coefficients in our empirical results. We are concerned that students posing more questions are negatively associated with exam score. This result suggests an inadequacy of the discussion board as a means for the average student to resolve questions about the material.

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APPENDIX TABLE

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time on Pop-quizzes	0.0232	0.0541	0.033
	-0.33	-0.54	-0.44
attempts of Pop-quizzes	-6.263	-10.44+	-6.514
	(-1.11)	(-1.72)	(-1.23)
Math SAT score	0.0266		0.0294
	-1.44		-1.33
Verbal SAT score	0.0109		0.0124
	-0.7		-0.67
GPA	3.19+		3.026
	-1.66		-1.27
Sophomore	-5.251		-4.977
	(-1.06)		(-0.83)
Junior	0.403		0.719
	-0.08		-0.11
Senior	-2.83		-2.638
	(-0.48)		(-0.36)
LS: Verbal	-1.929		-2.404
	(-0.32)		(-0.31)
LS: Auditory	3.464		3.983
	-1.29		-1.17
LS: Reading	-5.15+		-5.675
	(-1.73)		(-1.50)
LS: Kinesthetic	-5.095*		-5.223+
	(-2.09)		(-1.67)
Blended Format	-0.706		-1.027
	(-0.23)		(-0.30)
Online Format	-3.552		-4.665
	(-0.94)		(-1.05)
Constant	29.32*	62.22***	30.15*
	-2.19	-4.53	-2.08
Observations	148	148	148
R Sq	0.6171	0.3309	0.6213
F	8.69	2.59	
Prob > F	0.0000	0.0074	
Wald chi2			133.29
Prob> chi2			0.0000
t statistics in parentheses	+ $p < 0.10$ * p < 0.05, ** p < 0.01, *** p < 0.001		