Assessing the effect of online homework on exam performance: A large sample size experiment.[1]

Steve Trost[2] & Djavad Salehi-Isfahani
Virginia Tech

Abstract:

Using a large sample and unique quasi-experimental method, we assess the effect of online homework completion on topic-specific exam performance in large Principles of Microeconomics classes. Overall, results from the first third of the course suggest that the completion of the assigned homework is positively (if not always significantly) correlated with higher scores on related midterm questions. However, these results are not found to be uniform across genders, thus suggesting a line of future research. In addition, any affect that homework completion has on exam performance is limited to the midterm. Performance on the final is found to not be significantly influenced by homework completion.

Key Words: undergraduate economics education, online homework.

JEL Classification: A22, C93

[1] Draft is very preliminary, please do not cite. Comments are most welcome.
[2] Contact author. *Email*: strost@vt.edu *Postal address*: Department of Economics (0316), Virginia Tech, Blacksburg, VA 24061.
*Acknowledgements: We'd like to thank Chris Makler and the folks at Aplia for being very helpful. We'd also like to thank Paul Romer who initially suggested the idea for this project several years ago.

1. Introduction:

Over the past decade, the use of online homework systems in teaching of principles of economics has increased sharply. Enrollment in Aplia, the largest of these systems, has increased from 25,000 students in 2003 to 225,000 students in 2009. Proponents of these systems argue that they make it possible to assign meaningful homework to students in large lecture classes without imposing an undue grading burden on the instructor or TA. While these online homework programs cannot replicate traditional pencil and paper assignments, they can engage the students and require them to think about the topics outside of the lecture hall. As with any new teaching or learning tool, the question of efficacy is an important one. Does the completion of online homework assignments have a significant effect on a student's exam performance?

We try to answer this question in an experimental setup using the Aplia online homework system. While several studies have attempted to answer this question using experimental methods (*see* Lass, Morzuch, and Rogers (2007) and Emerson and Mencken (2008)), our approach is unique in a couple of ways. First, we focus on the effect of homework assignment and completion on *individual topics* taught during a Principles of Microeconomics course. By allowing students to skip homework assignments pertaining to particular topics with no grade penalty, we can assess whether the completion of these assignments affects exam performance on questions related to those topics. Second, because our experiment can be run entirely within one class, we eliminate any class-specific effects (such as student selection based on the hour of the day that the class is held) that may confound the results of other studies that use separate classes as their treatment and control groups.

A serious problem that randomized experiments of homework assignment face is that it is not possible (from a fairness standpoint) to *prevent* students from doing a homework assignment.

So whereas making a particular homework optional or not can be randomly assigned, actual completion of the homework cannot. But, as one would expect, assignment is highly correlated with completion, so the experiment produces a strong instrument with which the effect of completion on exam grade can be identified. As such, in addition to simple OLS analyses, we consider an instrumental variables approach similar to that of Angrist (1990) and Bloom, et.al. (1997).

Although not always strongly statistically significant, results suggest that homework completion is positively associated with higher midterm exam scores for all three topics considered. This effect, however, is found to disappear when the topic-specific scores on the final exam are used as our regressors. We attribute this to the fact that specific skills taught by early homework are learned later through other means, especially after the first midterm reveals gaps in a student learning, which may prompt remedial action. While a student might fall behind his/her classmates because he/she did not complete a homework assignment, that gap in understanding likely closes as the topic is revisited over the course of the semester.

We are also interested in how the effect of homework on student performance varies by student characteristics, such as gender and year in school. While results pertaining to year in school suggest no systematic relationship, results are shown to vary greatly by gender.

Section two briefly discusses existing literature pertaining to the relationship between effort and performance as well as literature related to performance in principles of economics courses. Section three describes the experimental structure, while section four presents descriptive statistics and discusses experiment validity. In section five we present our analysis methodology and results. Section six concludes.

2. Literature

This work fits into the larger literature concerning the effectiveness of different pedagogical practices, and specifically lies at the intersection of the use of technology in the classroom and the role of homework and effort in learning. By and large, existing literature suggests that students who complete homework (either online or traditional) perform better on exams. For example, in a unique small-sample study performed at Berea College, Stinebrickner and Stinebrickner (2008) find that study time and effort have a positive and significant effect on overall GPA during the first semester in college. Using non-experimental methods, Rich (2006) finds that students who put in more effort (as measured through class attendance and attempting homework problems) perform better on exams in senior-level corporate finance classes. Since homework completion and attendance is not required in Rich's study, higher quality students are more likely to complete homework assignments *and* do better on exams, thus causing a potential endogeneity problem.[1]

More closely related to the current research, Lass, Morzuch, and Rogers (2007) find that the use of online homework systems and the use of in-class response systems ("clickers") improve student performance in large introductory statistics classes. Emerson and Mencken (2008) find that students in classes where completion of online homework assignments is mandatory score higher on final exams than students in classes where the same assignments are optional. These and other similar studies apply different conditions to different classes, making it impossible to control for unobserved differences between those classes. Our study is unique in that the experiment can be performed within the context of one class (and repeated for other classes). Our methodology also makes it possible to study the effect of effort on a topic-by-topic

[1] While Rich does try to control for this issue by using other measures of ability, such as SAT scores, it is nearly impossible to truly separate the two effects.

level. In addition, our paper makes use of a sample size that is much larger than those used in other papers in this literature.

Also relevant to the current study is the recent paper by Elzinga and Melaugh (2009) that uses an unprecedented 20-year data set to examine the determinants of grades in principles of microeconomics courses. Among other things, they find that males and upperclassmen perform better in the principles courses studied.

3. Experiment design:

In our study, we divide the syllabus of a Principles of Microeconomics course into three parts or periods with a non-cumulative exam at the end of each part, and a cumulative final at the end of the semester. Each part contains several homework assignments, three of which we use in the experiment. For each of these three assignments, we randomly select one third of the class to "skip" the assignment. We refer to these students as the "treatment group" (with the remaining students referred to as the "control group"). We encourage students in the treatment group to complete the optional assignment but assure them that it will not count toward their homework grade.[2] Each student "skips" only one homework assignment per midterm. The midterm contains a number of questions related to each of the topics covered by those assignments as well as questions on topics for which everyone was required to do the homework assignments (we refer to these as "zero topics"). Table 1 shows the topics covered in the class with the nine topics included in the experiment market by an asterisk. For the reasons noted earlier, we focus on the first three homework assignments. The final contains questions related to all experimental

[2] In these classes, homework counts for 16% of the student's grade (roughly 1% per required homework assignment).

assignments (and, again, a number of questions pertaining to topics for which all students were required to do the homework assignments).

In essence what we are doing is removing some of the incentive to do the homework for the treatment group (the third of the class that is allowed to skip the homework with no penalty). While all students have some incentive to complete the homework (presumably to aid understanding of the topic), those in the control group have a stronger grade-based incentive to do so. Depending on the homework assignment, 24-44% of students chose to complete the homework whether or not they had this grade incentive (see table 5b) while other students (41% in both classes combined) chose to never complete a homework assignment unless the grade incentive existed. Thus we really have two levels of information: the incentive level (which we controlled) and the completion or motivation level (which the student controlled). Using the results of the midterm and final exams, we see whether students who completed a particular assignment scored better on related questions than those who were did not complete the assignment. We also look at the effect of the grade incentive alone by looking at differences in exam performance between the treatment and control groups. For reasons discussed below, neither of these specifications correctly measure the effect of homework completion on exam performance. We therefore present two alternative approaches that more closely capture this effect.

4. Summary of the data and experiment validity:

Data are taken from two principles of microeconomics classes taught during the same semester. Only students who completed the course were included in the analysis. These classes had the same teacher (Trost), used the same book, and were assigned the same homework. The only

significant difference concerns the size of these two classes. One is quite large (547 students) and the other is relatively small (135 students). Table 2 shows the student make-up for each of these classes. Aside from a slightly higher proportion of juniors and seniors in the small class, the two are quite similar. Student effort or motivation (as measured by the number of "optional" assignments completed throughout the entire course), is fairly equal with the smaller class showing a slightly higher effort level.

Experiment validity requires that the distribution of observable exogenous characteristics (in this case gender and year in school) of the treatment and control groups be similar and that the variable of interest (in this case homework completion) show ample variation. If this is not the case then the effect of the exogenous characteristic may be confounded with the effect of homework completion. Exogenous variables are found to be similar for the two groups for all topics (see table 3). In addition, as seen in table 5b, completion rates differ considerably between the treatment (not assigned) and control (assigned) groups.

5. Data analysis, results and discussion:

5.1 Descriptive statistics:

Before delving into the analysis concerning the effect of homework on exam performance, it is useful to consider differences in performance across exogenous and observable characteristics. Table 4 shows performance (as measured by homework scores, exam scores, in-class "clicker" scores, and the final course score) by gender and year for each class. By and large, while women perform better on homework and in-class "clicker" questions, men perform better on exams. Overall, men perform slightly better than women in the course. When considering year in school, there appears to be a slight but inconsistent upward trend, with more advanced students

performing better than their younger classmates. Table 5a shows the number of optional homework assignments completed by gender and year in school for both classes combined. While we see some differences in effort depending on year in school, effort as measured here does not vary significantly with gender. This result is interesting in light of the higher homework and clicker (class participation) scores earned by female students along with the conventional wisdom that female students, on average, put in more effort than their male counterparts. In table 5b we present homework completion rates by gender and assignment status. Here we do see a difference across genders, especially early in the course, with females completing homework more often than males regardless of assignment status. Tables 6a and 6b show average score on topic-specific midterm problems for all topics by completion and assignment status, respectively. By and large, those who completed the relevant homework assignment performed better than those that did not. When looking at assignment rather than completion, this difference is much smaller. This result is not surprising given the fact that many students who were not assigned a given homework completed it anyway.

5.2 Regression analysis:

The main challenge in estimating the effect of homework completion on student exam performance is the fact that random assignment only affects the incentive to do the homework rather than the actual completion (since students were not *prevented* from completing any of the assignments). As such, the straightforward experimental results pertain to the effect of incentives on a student's performance (through assigning the homework for a grade) rather than the effect of actually doing the homework. In other words, differences in topic-specific exam scores between the treatment and control groups identify the effect of increasing the incentive to do the assignment. This effect is less interesting since there is no theoretical link between the

incentive to do homework and learning, except in that it increases the likelihood of actually doing the homework. Therefore, we devote most of this space to the identification of the latter impact.

The effect of homework *completion* on exam performance:

While our experiment only determined the assignment (for a grade) of each homework, this variation in assignment led to variation in homework completion. As such, our first attempt to find the effect of homework completion on exam performance consists of a simple OLS model regressing topic-specific midterm scores (percentage correct on questions pertaining to that topic) on a dummy variable that equals one if the student completed the homework assignment. Since there are nine topics used in the experiment, this, and all other specifications presented *could* involve nine separate regressions (18 if repeated using the final exam instead of the midterm exam). However, we choose to only examine the first three topics in this paper. This is partly a matter of convenience – discussing nine separate results for each specification becomes quite burdensome. Focusing on the topics presented prior to the first exam also eliminates any potential endogeneity problems that may arise if students change their homework-related behavior in response to their first exam grade. In addition, these first topics set the stage for the rest of the course and therefore arguably take on additional importance. While we focus on midterm scores, some of the analysis is repeated using final exam scores.

Tables 7 present the results of simple OLS regressions of exam performance on homework completion for topics 1-3. The first column (specification A1) includes no covariates but for a dummy for the small class. The second column (specification A2) adds the student's gender and year in school. As can be seen in table 7, the effect of doing the homework appears to be significant in all cases. To better understand what the coefficients mean, a coefficient of X

on the completion dummy means that completion of the homework assignment is consistent with an X% increase in the percentage of topic-specific questions that the student answered correctly. Using the results from specification A2 along with the average percentage correct per topic and the number of questions per topic, this roughly translates to an increase in the number of correct questions of 0.3, 0.5, and 0.6 for topics 1, 2 and 3, respectively.

The principal problem with specification A2 is the fact that we have not accounted for ability and effort. This omission causes particularly acute problems here since the best students in terms of ability and/or effort are most likely to complete homework (whether required or not) *and* are most likely to perform well on exam regardless of homework completion. As a result, the coefficients posted in specifications A1 and A2 of table 7 are likely to be biased upward relative to the true effect of homework completion. Several studies attempt to control for ability/effort[3] by including students' SAT scores or high school or college GPA.[4] Since we do not (yet) have access to such data, we have to measure ability/effort in another way. We instead add a variable representing the student's score on exam questions that pertain to topics not involved in the experiment (as noted above, we call these "zero topics"). Because they were not part of the experiment, all students were required to complete homework assignments on these topics. In addition, since these topics were presented before the "experimental" topics for the first midterm, there is little chance that a skipped homework assignment on a later topic will affect exam scores on these topics.[5] A student's score on these problems should capture not only the student's predisposition to economics, but also their overall preparation for the exam, thus

[3] These two are almost impossible to distinguish so we will treat them as one.
[4] See, for example, Emerson and Mencken (2008), and Rich (2006).
[5] In table 1, the "zero topics" used are labeled "0(MT1)".

leaving only the marginal effect of homework completion to the completion dummy.[6] As can be seen in table 7, specification A3, the addition of these "zero topic" variables improves explanatory power of the model but does not qualitatively change the results. The only notable difference is a slight and expected decline in the size of the coefficients attached to homework completion.

The effect of homework *assignment* on exam performance:

While the focus of this paper is the effect of homework completion on exam performance, it may be interesting to look at the effect of the *assignment* of the homework rather than the *completion*. After all, this is the factor that the experiment actually controls. In addition, since assignment is under the control of the instructor, the effect of simply assigning homework for a grade in an interesting issue from an instructional standpoint.

Table 8 is identical to table 7 with the *assignment* of the homework (for a grade) replacing the *completion* of the homework. In the simplest specification (Specification B1), simply being assigned the homework is consistent with a statistically significant increase in exam performance only for topic 2 (although topic 3 comes close to significance). In addition, for those topics, the coefficients are less than half the size of the comparable coefficients in the specification using homework completion rather than assignment. Aside from a flip-flop in significance of topics 2 and 3, the addition of control variables in specifications B2 and B3 does not significantly change the nature of the results.

While the coefficient on the completion dummy discussed above overstates the effect of homework completion, the coefficient on the assignment dummy could be seen as a lower bound on the effect of homework completion. While not statistically significant for two of the three

[6] In some ways, however, this variable is superior to SAT scores in that it arguably captures innate ability in economics more than standardized tests might.

topics, results still suggest that the group with a higher percentage of homework completion performs better on the exam. Given the size of our sample and the low probability that some unobserved factor is driving these results, one can still argue that completing the homework does have some positive effect on exam performance. While these results are clearly much weaker than the completion results above, they indicate that the act of assigning homework for a grade does likely help exam performance by encouraging students to complete the assigned homework.

The role of gender

One question of interest is whether the effects we are seeing are similar across gender and year in school. Elzinga and Melaugh (2009) find that males and upperclassmen perform better overall in economics classes. Above we reported that while males performed better on exams, females performed better on homework assignments. Given this result, it may be reasonable to suspect that the relationship between homework and exam performance may differ across the genders, and possibly across year in school. To explore this possibility, we re-run the above regressions adding interaction terms for both gender and year in school.[7] While we find no compelling evidence that the effect of homework completion on exam performance differs systematically by year in school (perhaps because a large portion of our students are freshmen and sophomores), we do find reason to further investigate the role of gender in the relationship between homework completion and exam performance. Running both our *completion* and *assignment* regressions for males and females separately (table 9) produces some interesting but troubling results. Looking at the results using the *completion* dummy (table 9a) we see that homework completion has a much larger effect on exam scores for men than for women. In fact for topics 1 and 2, the effect for women is not significantly different from zero (and is negative for topic 1). Using the *assignment* dummy (table 9b) produces different but more insignificant

[7] Results not shown.

results. While the coefficient on homework assignment is smaller and less significant for female students for topics 1 and 2 (and again is negative for topic 2), it is much larger than for their male counterparts for topic three. It is interesting to consider these results in light of the coefficient on the gender dummies in tables 7 and 8. Results of both of those specifications reveal that the gender gap is greatest for topic 3 and least for topic 2. This pattern may suggest that, for females, doing the homework may not help for topic 3 and that *not* doing the homework may not hurt for topic 2. Beyond that observation, we do not at this time have a good explanation for these results. The differences we see across gender are perhaps a worthy topic for future research.

As previously noted, the simple OLS specifications at best provide upper and lower bounds on the true effect of homework completion on exam performance. Next we employ two alternative methods intended to more accurately estimate this effect.

When assignment and completion are the same – a study of "compliers"

The first method takes a very intuitive approach to the issue but does so at the cost of throwing out observations. This specification repeats the main analysis using homework *completion* (specification A3) but only for students that, prior to midterm 1, never completed an optional homework and never failed to complete an assigned homework (a group that Angrist and Pischke (2009) refer to as "compliers").[8] In effect we are choosing the sample to eliminate the difference between the completion and assignment dummies – for these students, assignment and completion are the same. This approach is interesting for two reasons. First, it eliminates the issues noted above caused by those more motivated students who completed the optional

[8] Depending on the topic, for the three topics included here, 38-44% of the students in the treatment group decided to complete the optional homework while 3-7% in the control group decided not to complete the required homework – see table 5b.

homework assignments. Second, it focuses on the students that arguably are more responsive to grade incentives.

Table 10 shows the results of this method. While the coefficients on the completion variable are positive for all three topics they are only statistically significant for topics two and three. In terms of the size of the effect, while coefficients for topics 2 and 3 lie between those shown in tables 7 and 8, the coefficient for topic 1 falls below those presented earlier. As above, when the regressions are run separately for males and females, we find a large difference in terms of topic 2 with males clearly benefitting from homework completion and females clearly not.

Instrumental variables

The second method keeps all observation and takes advantage of the relationship between assignment and completion. Since students who are assigned the homework for a grade are much more likely to complete the homework, and since assignment is randomly and exogenously determined, we can simply use assignment as an instrument for completion. Conceptually, this method is similar to that used by Angrist (1990) when he was trying to determine the effect of military service on earnings. In that study, draft eligibility was used as an instrument for service just as here we can use homework assignment as an instrument for completion. Future earnings in Agrist's study correspond to exam scores here. In addition to calculating a simple Wald estimator as Angrist does, we also add covariates and run a full IV estimation.

Table 11a shows the results of this method with no covariates used. This specification identifies the effect of homework completion on exam performance assuming that the treatment effect is the same for all individuals regardless of whether or not they completed the homework assignment. Basically this specification assumes the treatment and control groups are identical

but for the fact that the control group was much more likely to complete the homework assignment. If true, this would mean that any observed difference in exam performance results from completion of the homework. Computationally, the coefficients are calculated by dividing the mean difference in scores between the "assigned" group and the "not assigned" group and dividing that difference by the corresponding difference in homework completion rates. This estimator is referred to as a Wald estimator and it is the simplest way to estimate the "local average treatment effect" of homework completion. As expected, results lie between the two extremes presented in tables 7 and 8. However, these results are only statistically significant (at at least the 5% level) for topic 2.

The calculations of the Wald estimators shown in table 10a do not allow for covariates to influence either the decision to complete the homework or performance on the exam. By allowing for covariates, we estimate what Angrist and Pischke (2009) refer to as a "weighted average of covariate-specific local average treatment effects"[9] Since we do not have a (very) large sample size, there is some likelihood that the control and treatment groups are different according to characteristics such as gender, year in school, and ability/effort. Adding covariates accounts for these differences. As seen in table 11b, while the addition of covariates produces a few differences in the results, the most notable of these differences are limited to results that are statistically insignificant in both specifications. Overall, while not strongly statistically significant (now only topic 3 shows meaningful significance)[10] results of the "full" IV model using all students suggest that homework completion does have a positive effect on exam performance. Coefficients in the 4-5 range suggest a 0.2-0.3 point improvement per topic on the midterm.

[9] Angrist and Pischke (2009), p. 178.
[10] This is not surprising in an IV estimation

Since we found differences across gender in the previous results, we repeat the Wald and "full" IV results for men and women separately. Results are shown in table 11. Here we find that both genders benefit from the homework for topics 1 and 3 with females showing a higher benefit on topic 3 than males (although the results are, for the most part, not statistically significant). As with the other specifications, males benefit from topic 2 homework whereas females do not. Once again, at this time we have no explanation for this pattern and it may be worth investigating in later work

Homework and final exam performance:

Above we focused on student performance on the first midterm. Another interesting question is whether or not the effect of these homework assignments carries through to the final exam. To find out, we reran all four specifications replacing midterm performance with final exam performance (on questions related to each topic). We also replace the "zero topic" variable with a new "zero topic" final exam variable that is the student's final exam score on all topics not involved in the experiment. This variable not only picks up some of the student's natural ability in economics (as the midterm 1 "zero topic" variable did) but also may pick up some of the effort that the student put into the class outside the relevant homework assignments.

While we only include results of the "full" IV estimation (table 12), results from all four specifications[11] suggest the same thing: whatever advantage a student may have gained by completing the homework on the first midterm mostly fades away by the time the final is taken. The only positive and significant result comes from topic 2 using specification A3 (which has an upward bias as discussed above).[12] This is perhaps to be expected since much of the rest of a principles class builds upon topics learned in the first few weeks of the class. In addition,

[11] Results are not included to preserve space. The authors can provide them upon request.
[12] The coefficient for topic 3 for females in the IV estimate is negative and significant.

students see these topics on midterms and practice exams throughout the course. In other words, students will get substantial practice with these topics regardless of whether or not the homework was completed. So while homework completion early on gets the students off to a good start, not completing homework early in the course does not lead to irreversible harm when it comes to the final exam.

6. Conclusion:

Using a rich set of data extracted from two principles of microeconomics classes taught during the same semester, we attempt to gain insight into the relationship between homework completion and exam performance on a topic-by-topic basis. Most important in our eyes is the conclusion that completing homework (in this case using Aplia) early in the course appears to improve exam performance. However, the results often exhibit weak statistical significance and the fact that in many (but not all) cases, males appear to benefit more from homework completion than do females raises more questions. In addition, any advantage a student gets through completing homework assignments appears to fade by the time the final is taken.

References:

Angrist, Joshua D. (1990), "Lifetime Earnings and the Vietnam Era Draft Lottery: Evidence from Social Security Administrative Records," *The American Economic Review*, 80, 3, pp. 313-336.

Angrist, Joshua D. and Jörn-Steffen Pischke, *Mostly Harmless Econometrics*, Princeton University Press: Princeton, NJ, 2009.

Bloom, Howard S., et.al. (1997), "The Benefits and Costs of JTPA Title II-A Programs: Key Findings from the National Job Training Partnership Act Study," *The Journal of Human Resources*, 32, 3, pp. 549-576.

Elzinga, Kenneth G. and Daniel O. Melaugh (2009), "35,000 Principles of Economics Students: Some Lessons Learned," *Southern Economic Review*, 76, 1, pp. 32-46.

Emerson, Tisha L.N. and Kimberly D. Mencken (2008), "Homework: To require or not? Online Graded homework and Student Achievement," Working Paper.

Lass, Daniel A., Bernard J. Morzuch and Richard T. Rogers (2007), "Teaching with Technology to Engage Students and Enhance Learning," *University of Massachusetts Amherst Department of Resource Economics Working Paper*, 2007-1.

Rich, Steven P. (2006), "Student Performance: Does Effort Matter?" *Journal of Applied Finance*, 16, 2, pp. 120-133.

Stinebrickner, Ralph and Todd Stinebrickner (2008), "The causal Effect of Studying on Academic Performance," *The B.E. Journal of Economic Analysis & Policy*, 8, 1, 14 pp. 1-53.

Table 1: Topics

Topic Number	Topic	Chapter(s) in text**
0 (MT1)	Introduction to economic terms and ideas.	1,2
1*	Introduction to Supply and Demand	4
2*	Elasticities	5
3*	Consumer Behavior	6
0 (MT2)	Introduction to firms (production and costs)	7
4*	Perfect Competition	8
5*	Monopoly	9
6*	Monopolistic Competition and Oligopoly	10
0 (MT3)	Antitrust	15
0 (MT3)	Resource Markets	11-13
7*	Firm Structure and Imperfect Information	15
8*	Public Goods and Public Choice	16
9*	Externalities	17
10	Income Inequality	18
11	Taxes	Various
12	International Trade	19

* Included in experiment

** Text used was "Microeconomics: A Contemporary Introduction, 8e" by McEachern

Topics 10-12 are presented after the final midterm and are not included in the experiment.

Table 2: Class statistics

	Class 1 (n=547)	Class 2 (n=135)
Gender		
Males	57.04%	59.26%
Females	42.96%	40.74%
Year in School		
Freshmen	29.62%	30.37%
Sophomores	60.88%	51.85%
Juniors	6.40%	8.89%
Seniors	2.74%	8.15%
Other	0.37%	0.74%
Effort level*		
0	41.50%	39.26%
0.5	7.50%	5.93%
1	23.58%	20.00%
1.5	7.68%	5.19%
2	10.42%	14.07%
2.5	3.11%	2.96%
3	6.22%	12.59%

* As measured by number of optional homeworks attempted. Students get a 1 if they get >50% on the assignment and a 0.5 if they do the assignment but score less than 50%.

Table 3: Experiment Validity

		Topic 1	Topic 2	Topic 3
Gender (% Male)				
Treatment		59.2%	55.4%	57.7%
Control		56.6%	58.5%	57.4%
Year in School				
Treatment	**Freshman**	29.2%	29.7%	30.4%
	Sophomore	60.9%	58.1%	58.2%
	Junior	6.9%	7.7%	6.2%
	Senior	2.6%	4.5%	4.4%
	Graduate	0.4%	0.0%	0.9%
Control	**Freshman**	30.1%	29.8%	29.5%
	Sophomore	58.1%	59.6%	59.6%
	Junior	6.9%	6.5%	7.3%
	Senior	4.5%	3.5%	3.5%
	Graduate	0.5%	0.7%	0.2%

Table 4: Performance by gender and year in school

	n	Homework score	iClicker score	Midterm 1 Score	Midterm 2 Score	Midterm 3 Score	Final Exam Score	Course Score
Class 1								
Men	310	81.69	66.90	71.31	64.36	62.86	72.55	78.78
Women	234	84.55	72.74	68.93	59.89	63.61	70.51	77.52
Freshmen	162	81.26	70.27	69.28	62.41	60.79	70.88	77.29
Sophomores	331	83.58	68.81	70.14	62.04	63.59	71.58	78.31
Juniors	35	84.49	73.24	76.29	64.63	69.66	75.63	81.65
Seniors	14	80.45	61.96	67.86	63.43	62.14	70.64	76.74
Graduate	2	97.01	85.00	88.00	85.00	83.00	89.00	94.72
Class 2								
Men	80	81.16	68.50	73.73	60.05	62.93	69.84	79.12
Women	55	83.53	73.28	69.89	60.47	61.05	65.29	77.49
Freshmen	41	80.70	76.54	74.39	62.20	61.27	70.46	80.53
Sophomores	70	83.14	74.15	69.83	58.46	62.91	66.49	77.24
Juniors	12	85.23	48.50	76.17	67.83	67.00	72.00	80.75
Seniors	11	76.73	48.64	73.45	73.45	61.09	64.36	76.11
Graduate	1	91.67	64.91	82.00	72.00	-	63.00	76.32

Table 5a: Effort levels by gender and year in school

		Effort level							
	n	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**Mean**
All	682	41.1%	7.2%	22.9%	7.2%	11.1%	3.1%	7.5%	**0.90**
Men	392	40.8%	6.6%	24.2%	6.4%	12.5%	3.3%	6.1%	**0.89**
Women	290	41.4%	7.9%	21.0%	8.3%	9.3%	2.8%	9.3%	**0.91**
Freshmen	203	38.4%	8.9%	21.2%	9.4%	11.8%	3.9%	6.4%	**0.92**
Sophomores	403	43.9%	7.4%	21.8%	6.7%	10.9%	2.5%	6.7%	**0.84**
Juniors	47	29.8%	0.0%	36.2%	4.3%	14.9%	2.1%	12.8%	**1.16**
Seniors	26	38.5%	0.0%	30.8%	3.9%	3.9%	7.7%	15.4%	**1.10**
Other	3	33.3%	33.3%	0.0%	0.0%	0.0%	0.0%	33.3%	**1.17**

* As measured by number of optional homeworks attempted. Students get a 1 if they get >50% on the assignment and a 0.5 if they do the assignment but score less than 50%.

Table 5b: Homework completion percentages by assignment status and gender

	Topic 1	**Topic 2**	**Topic 3**	**Topic 4**	**Topic 5**	**Topic 6**	**Topic 7**	**Topic 8**	**Topic 9**
All, assigned	96.8%	94.9%	93.4%	92.8%	94.5%	93.4%	89.1%	92.0%	81.0%
Men, assigned	96.0%	93.6%	91.2%	90.0%	94.0%	91.5%	86.3%	90.4%	76.4%
Women, assigned	97.9%	96.8%	96.4%	96.7%	95.2%	95.8%	93.2%	93.9%	87.1%
All, not assigned	44.4%	38.5%	38.1%	35.2%	31.7%	34.8%	29.4%	32.6%	24.4%
Men, not assigned	42.3%	35.0%	36.4%	40.8%	30.5%	33.6%	29.9%	31.6%	24.4%
Women, not assigned	47.4%	42.9%	40.4%	28.3%	33.3%	36.7%	28.8%	34.1%	24.5%

Table 6a: Average score on midterm exam sections by completion status and gender

	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8	Topic 9
All, completed	71.9%	66.2%	72.6%	64.1%	71.5%	64.0%	74.2%	63.5%	65.5%
Men, completed	73.9%	67.2%	75.5%	67.2%	73.0%	65.8%	73.4%	63.1%	65.5%
Women, completed	69.4%	64.9%	69.0%	59.8%	69.5%	61.9%	75.4%	64.0%	65.5%
All, not completed	67.8%	58.9%	64.0%	59.6%	67.0%	57.0%	73.1%	55.7%	61.9%
Men, not completed	67.0%	58.2%	66.5%	62.5%	68.8%	57.3%	73.2%	55.3%	61.8%
Women, not completed	69.2%	60.0%	59.8%	56.1%	64.6%	56.5%	73.0%	56.6%	62.0%

Table 6b: Average score on midterm exam sections by assignment status and gender

	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8	Topic 9
All, assigned	71.5%	65.7%	71.4%	63.8%	70.5%	62.2%	73.0%	62.7%	64.1%
Men, assigned	73.1%	66.7%	73.5%	66.6%	72.0%	64.1%	72.4%	62.0%	63.7%
Women, assigned	69.4%	64.4%	68.6%	59.7%	68.6%	59.7%	73.9%	63.5%	64.5%
All, not assigned	70.2%	61.9%	68.5%	61.2%	69.9%	62.3%	75.6%	58.7%	64.3%
Men, not assigned	70.9%	61.3%	72.1%	64.6%	71.5%	62.0%	75.3%	58.2%	64.6%
Women, not assigned	69.2%	62.7%	63.6%	57.1%	67.7%	62.6%	76.0%	59.3%	63.9%

Table 7: OLS using homework completion

n=676	Specification A1			Specification A2			Specification A3		
	Topic 1	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**
Homework Completion	4.154 **	7.219 **	8.684 **	4.108 **	7.269 **	8.968 **	2.810 *	5.146 **	7.073 **
	1.555	*1.631*	*1.698*	*1.548*	*1.630*	*1.676*	*1.422*	*1.498*	*1.501*
Class 2 Dummy (small)	1.827	4.528 **	3.462	1.509	4.600 **	3.235	1.735	4.954 **	3.541 *
	1.593	*1.735*	*1.840*	*1.595*	*1.747*	*1.826*	*1.461*	*1.594*	*1.629*
Gender				-2.990 *	-1.060	-6.250 **	-2.720 *	-0.746	-5.878 **
				1.284	*1.406*	*1.471*	*1.176*	*1.283*	*1.312*
Sophomore				0.562	-0.118	-0.477	0.975	0.331	0.100
				1.423	*1.558*	*1.629*	*1.303*	*1.422*	*1.454*
Junior				5.213 *	3.748	6.745 *	2.441	0.554	3.188
				2.658	*2.910*	*3.043*	*2.446*	*2.668*	*2.727*
Senior				1.449	-4.976	-3.204	1.547	-5.070	-3.349
				3.440	*3.766*	*3.939*	*3.149*	*3.435*	*3.513*
Graduate				21.369 *	17.051	7.308	14.978	9.339	-1.416
				9.554	*10.456*	*10.930*	*8.765*	*9.560*	*9.770*
Zero Topic Score							0.589 **	0.661 **	0.759 **
							0.052	*0.057*	*0.058*
Constant	67.436 **	58.065 **	63.246 **	67.960 **	58.388 **	65.635 **	24.272 **	9.892 *	9.428 *
	1.423	*1.461*	*1.523*	*1.760*	*1.874*	*1.911*	*4.159*	*4.497*	*4.603*
Adjusted R-squared	0.009	0.036	0.039	0.024	0.039	0.069	0.181	0.201	0.260

** significant at the 1% level

* significant at the 5% level

Table 8: OLS using homework assignment

n=676	Specification B1			Specification B2			Specification B3		
	Topic 1	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**
Homework Assigned	1.289	3.832 **	2.910	1.332	3.705 *	2.884	2.320	2.425	3.053 *
	1.344	*1.489*	*1.586*	*1.336*	*1.489*	*1.566*	*1.221*	*1.358*	*1.389*
Class 2 Dummy (small)	1.713	4.704 **	3.266	1.384	4.791 **	3.081	1.653	5.096 **	3.435 *
	1.600	*1.752*	*1.870*	*1.602*	*1.764*	*1.860*	*1.461*	*1.604*	*1.650*
Gender				-2.845 *	-0.725	-5.809 **	-2.646 *	-0.508	-5.522 **
				1.289	*1.419*	*1.496*	*1.175*	*1.290*	*1.327*
Sophomore				0.569	-0.219	-0.313	1.014	0.273	0.243
				1.429	*1.574*	*1.659*	*1.304*	*1.431*	*1.472*
Junior				5.421 *	3.819	7.101 *	2.515	0.522	3.309
				2.669	*2.940*	*3.099*	*2.446*	*2.686*	*2.762*
Senior				1.581	-5.147	-3.820	1.491	-5.201	-3.795
				3.456	*3.804*	*4.010*	*3.151*	*3.457*	*3.556*
Graduate				22.331 *	15.174	7.827	15.449	7.896	-1.058
				9.590	*10.572*	*11.145*	*8.762*	*9.627*	*9.905*
Zero Topic Score							0.604 **	0.676 **	0.787 **
							0.052	*0.057*	*0.058*
Constant	69.887 **	60.972 **	67.861 **	70.259 **	61.342 **	70.185 **	23.788 **	10.934 *	10.429 *
	1.132	*1.270*	*1.352*	*1.565*	*1.753*	*1.834*	*4.223*	*4.522*	*4.713*
Adjusted R-squared	0.000	0.017	0.006	0.015	0.020	0.034	0.181	0.191	0.241

** significant at the 1% level

* significant at the 5% level

Table 9: OLS specifications A3 and B3 run separately for males and females

9a: Completion	Males (n=389)			Females (n=287)		
	Topic 1	Topic 2	Topic 3	Topic 1	Topic 2	Topic 3
Homework Completed	4.821 **	7.554 **	7.586 **	-0.405	1.551	6.139 *
	1.748	*1.894*	*1.878*	*2.405*	*2.448*	*2.510*
Class 2 Dummy (small)	0.713	3.766	3.990	2.912	6.562 **	2.973
	1.832	*2.052*	*2.088*	*2.406*	*2.540*	*2.624*
Sophomore	1.101	-1.064	0.939	0.806	1.906	-1.594
	1.615	*1.809*	*1.840*	*2.197*	*2.326*	*2.399*
Junior	3.100	0.317	3.422	1.896	0.787	2.314
	2.969	*3.324*	*3.381*	*4.225*	*4.469*	*4.618*
Senior	3.191	-5.243	-1.350	-0.044	-4.767	-6.250
	4.230	*4.733*	*4.816*	*4.779*	*5.061*	*5.247*
Graduate	14.475	9.334	-0.198	(dropped)	(dropped)	(dropped)
	8.426	*9.428*	*9.590*	*0.000*	*0.000*	*0.000*
Zero Topic Score	0.620 **	0.621 **	0.699 **	0.542 **	0.715 **	0.853 **
	0.065	*0.073*	*0.074*	*0.085*	*0.091*	*0.093*
Constant	20.440 **	12.107 *	12.980 *	27.711 **	6.529	-1.429
	5.230	*5.857*	*5.955*	*6.748*	*6.936*	*7.214*
Adjusted R-squared	0.220	0.205	0.226	0.118	0.196	0.254

9b: Assignment	Males (n=389)			Females (n=287)		
	Topic 1	Topic 2	Topic 3	Topic 1	Topic 2	Topic 3
Homework Assigned	2.3815	4.5754 *	1.9231	2.1536	-0.5523	4.4139 *
	1.5375	*1.7870*	*1.8023*	*2.0129*	*2.1142*	*2.1980*
Class 2 Dummy (small)	0.5556	4.1419 *	3.6805	3.0076	6.6290 **	3.1322
	1.8448	*2.0764*	*2.1276*	*2.4002*	*2.5442*	*2.6336*
Sophomore	1.1884	-0.8570	1.0776	0.9216	1.8216	-1.5001
	1.6258	*1.8297*	*1.8755*	*2.1939*	*2.3223*	*2.4063*
Junior	3.2734	0.3782	3.3283	1.7337	0.5702	2.6988
	2.9887	*3.3636*	*3.4480*	*4.2171*	*4.4723*	*4.6281*
Senior	3.3754	-4.0824	-1.0863	-0.2199	-4.9186	-6.7442
	4.2596	*4.8057*	*4.9126*	*4.7718*	*5.0587*	*5.2531*
Graduate	15.3872	7.1402	-0.2415	(dropped)	(dropped)	(dropped)
	8.4757	*9.5534*	*9.7952*	*0.0000*	*0.0000*	*0.0000*
Zero Topic Score	0.6414 **	0.6398 **	0.7278 **	0.5544 **	0.7283 **	0.8746 **
	0.0654	*0.0736*	*0.0754*	*0.0855*	*0.0904*	*0.0929*
Constant	20.9525 **	13.0397 *	15.0316 *	24.9437 **	7.1872	-1.2886
	5.3113	*5.9452*	*6.1608*	*6.9009*	*6.9037*	*7.2718*
Adjusted R-squared	0.2092	0.1855	0.1956	0.1211	0.1954	0.2493

** significant at the 1% level

* significant at the 5% level

Table 10: OLS specification A3 using "compliers" only

	All students (n=360)			Males Only (n=208)			Females Only (n=152)		
	Topic 1	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**
Homework Completed	1.478	4.293 *	4.290 *	1.794	6.927 **	3.946	0.942	0.630	4.874
	1.743	*1.780*	*1.920*	*2.214*	*2.236*	*2.398*	*2.867*	*2.947*	*3.211*
Class 2 Dummy (small)	1.366	4.313 *	3.140	-0.351	2.106	4.511	3.523	6.529	0.353
	2.043	*2.147*	*2.328*	*2.698*	*2.796*	*3.019*	*3.315*	*3.504*	*3.817*
Gender	-0.869	-1.550	-7.186 **	-	-	-	-	-	-
	1.630	*1.713*	*1.859*	-	-	-	-	-	-
Sophomore	-0.014	-1.469	-0.105	0.073	-1.380	1.354	0.239	-1.468	-3.253
	1.825	*1.918*	*2.081*	*2.251*	*2.331*	*2.520*	*3.155*	*3.336*	*3.648*
Junior	0.465	0.513	8.633	1.448	3.574	10.741	0.085	-3.545	3.975
	3.921	*4.123*	*4.471*	*5.058*	*5.238*	*5.664*	*6.364*	*6.766*	*7.357*
Senior	-6.216	-7.522	-8.124	-6.746	-3.699	-1.096	-3.928	-8.759	-17.320
	5.622	*5.900*	*6.406*	*7.772*	*8.057*	*8.699*	*8.600*	*9.075*	*9.941*
Graduate	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Zero Topic Score	0.637 **	0.615 **	0.779 **	0.664 **	0.633 **	0.706 **	0.604 **	0.625 **	0.894 **
	0.071	*0.075*	*0.081*	*0.087*	*0.090*	*0.097*	*0.124*	*0.132*	*0.143*
Constant	21.957 **	15.849 **	10.561	19.995 **	12.930	14.758	23.274 *	15.737	-2.219
	5.645	*5.849*	*6.355*	*6.816*	*7.100*	*7.606*	*9.912*	*10.049*	*11.102*
Adjusted R-squared	0.178	0.174	0.251	0.209	0.210	0.218	0.113	0.123	0.227

** significant at the 1% level

* significant at the 5% level

Table 11: Instrumental Variables (Local Average Treatment Effects)

11a: No covariates	All students (n=676)			Males Only (n=389)			Females Only (n=287)		
	Topic 1	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**
Homework Completed	2.478	6.773 **	5.234	4.076	9.219 **	2.571	0.448	3.145	8.908 *
	2.549	*2.618*	*2.832*	*3.167*	*3.269*	*3.614*	*4.184*	*4.283*	*4.420*
Constant	69.119 **	59.304 **	66.525 **	69.210 **	58.048 **	71.156 **	68.975 **	61.361 **	60.016 **
	2.107	*2.119*	*2.252*	*2.574*	*2.611*	*2.798*	*3.539*	*3.532*	*3.640*
R-squared	0.009	0.029	0.031	0.027	0.047	0.023	.	0.010	0.036

Instrument = assigned

11b: With Covariates	All students (n=676)			Males Only (n=389)			Females Only (n=287)		
	Topic 1	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**
Homework Completed	4.369	4.306	5.521 *	4.418	7.710 **	3.485	4.146	-1.030	8.000 *
	2.284	*2.381*	*2.465*	*2.804*	*2.945*	*3.189*	*3.860*	*3.899*	*3.925*
Class 2 Dummy (small)	1.779	4.978 **	3.516 *	0.705	3.761	3.824	3.106	6.621 **	2.952
	1.453	*1.585*	*1.620*	*1.814*	*2.032*	*2.082*	*2.395*	*2.515*	*2.595*
Gender	-2.787 *	-0.716	-5.799 **	-	-	-	-	-	-
	1.172	*1.276*	*1.308*	-	-	-	-	-	-
Sophomore	0.977	0.326	0.136	1.110	-1.068	1.005	0.951	1.743	-1.653
	1.296	*1.413*	*1.446*	*1.600*	*1.791*	*1.832*	*2.186*	*2.310*	*2.374*
Junior	2.386	0.529	3.239	3.110	0.317	3.396	1.659	0.538	2.123
	2.432	*2.652*	*2.712*	*2.939*	*3.289*	*3.367*	*4.203*	*4.432*	*4.576*
Senior	1.444	-5.113	-3.481	3.231	-5.246	-1.105	-0.157	-5.132	-5.834
	3.133	*3.415*	*3.496*	*4.193*	*4.684*	*4.798*	*4.751*	*5.027*	*5.232*
Graduate	14.659	9.215	-1.557	14.557	9.351	-0.559	-	-	-
	8.722	*9.503*	*9.715*	*8.352*	*9.335*	*9.553*	-	-	-
Zero Topic Score	0.585 **	0.665 **	0.765 **	0.622 **	0.621 **	0.713 **	0.536 **	0.732 **	0.846 **
	0.052	*0.057*	*0.058*	*0.065*	*0.073*	*0.074*	*0.084*	*0.092*	*0.093*
Constant	23.413 **	10.232 *	10.113 *	20.618 **	12.035 *	14.878 *	24.392 **	7.423	-2.320
	4.251	*4.531*	*4.657*	*5.267*	*5.891*	*6.049*	*7.062*	*6.946*	*7.279*
R-squared	0.190	0.210	0.267	0.234	0.219	0.231	0.125	0.210	0.269

Instruments = smallclassdummy, sophomore, junior, senior, graduate, midterm 1 zero topic score, and assigned

** significant at the 1% level

* significant at the 5% level

Table 12: Instrumental Variables (Final Exam)

	All students (n=676)			Males Only (n=389)			Females Only (n=287)		
	Topic 1	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**	**Topic 1**	**Topic 2**	**Topic 3**
Homework Completed	0.561	2.652	-4.002	2.118	1.971	-1.959	-1.441	3.288	-7.202 *
	2.493	*2.625*	*2.250*	*3.031*	*3.329*	*2.890*	*4.265*	*4.160*	*3.566*
Class 2 Dummy (small)	1.424	-0.572	-1.034	-0.109	-0.894	-3.431	3.263	0.249	2.781
	1.597	*1.784*	*1.485*	*1.984*	*2.310*	*1.891*	*2.661*	*2.813*	*2.387*
Gender	-0.747	3.410 *	-4.065 **	-	-	-	-	-	-
	1.280	*1.426*	*1.194*	-	-	-	-	-	-
Sophomore	0.064	0.375	-1.157	-1.010	-0.372	-1.919	1.526	1.748	-0.080
	1.408	*1.570*	*1.310*	*1.728*	*2.009*	*1.647*	*2.376*	*2.517*	*2.131*
Junior	0.067	4.822	1.245	-0.186	1.844	-0.283	0.952	9.945 *	4.009
	2.634	*2.937*	*2.450*	*3.188*	*3.702*	*3.035*	*4.557*	*4.819*	*4.096*
Senior	0.033	-1.151	0.883	2.895	-4.470	2.485	-2.277	2.792	-0.480
	3.407	*3.798*	*3.170*	*4.555*	*5.283*	*4.334*	*5.188*	*5.509*	*4.705*
Graduate	-13.679	3.453	3.052	-14.397	2.579	3.735	-	-	-
	9.472	*10.555*	*8.800*	*9.069*	*10.518*	*8.623*	-	-	-
Zero Topic Score	0.867 **	1.085 **	0.704 **	0.871 **	1.096 **	0.623 **	0.858 **	1.068 **	0.811 **
	0.052	*0.058*	*0.050*	*0.067*	*0.078*	*0.065*	*0.083*	*0.088*	*0.077*
Constant	8.915 *	-23.268 **	33.866 **	8.295	-22.797 **	39.579 **	9.256	-20.665 **	22.864 **
	4.459	*4.884*	*3.977*	*5.548*	*6.352*	*5.151*	*7.264*	*7.440*	*6.028*
R-squared	0.303	0.000	0.259	0.319	0.359	0.215	0.277	0.375	0.274

Instruments = smallclassdummy, sophomore, junior, senior, graduate, final zero topic score, and assigned

** significant at the 1% level

* significant at the 5% level