Effectiveness of Online Learning: How Do Adaptive Learning Tools Improve Student Learning?

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Abstract: This paper investigates the effect of a particular online adaptive learning tool on student learning outcomes. The study finds that the online adaptive learning tool is not a good predictor for exam performance in contrast to post-lecture homework. Moreover, pre-knowledge of the model is positively associated with understanding of the model. Furthermore, target score or accuracy of responses on the adaptive learning tool does not have any positive effect on exam performance. Rather, those who completed the first homework performed better than those who did not. However, causality could not be confirmed.

Key words: adaptive learning; online learning; online pedagogy; economic education

JEL codes: A1, A2

1. Introduction

There has been a movement in higher education to increase graduation rate and to decrease cost. As a response, universities have adopted online courses or online components. This study focuses on a particular adaptive learning tool; *Learning Curve from Macmillan publisher*. *Learning Curve* is based on mastery learning and is used as a pre-lecture quiz. The conventional belief that preview benefits learning is tested. More precisely, this paper investigates if *Learning Curve* improves student-learning outcomes (SLO) as measured by midterm and final exam performance.

2. Literature Review

Many studies capture the effectiveness of all or some combinations of online class, pedagogy, and students' ability (Carter, 2012; Debord, Aruguete, & Muhlig, 2004; Nochols, Shaffer, & Shockey, 2003; Pargas, 2006). Brown & Liedhholm (2002) use online quiz in online and hybrid classes that perform worse in exam than the cohort in a face-to-face class. Foertsch, Moses, Strikwerda, & Litzkow (2002) studies reverse teaching using web-based homework, which measures the effectiveness in one course of combining flip class with online component. They show that first, online class is as effective as face-to-face class and second, online course materials are as good as off-line course materials. McGoldrick & Schuhmann (2013) show that challenge quiz, which supports mastery learning, improves students' engagement in class. They also find an improvement of initial in class quiz and total quiz grade. McKeown & Maclean (2013) show that participation in online quiz, measured by

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time spent and the number of attempts, is a good predictor of final exam performance, but not online quiz grade. This study uses the total number of visits of lecture videos and durations of watching videos to reflect a student's effort. Trost & Salehi-Isfahani (2012) studied the effectiveness of *Aplia* in Principles of Microeconomics class with an experiment data from multiple instructors and in different universities. Their results show that *Aplia* is a post-lecture homework moderately improves midterm performance on related questions and does not affect final performance. Regarding *Aplia* homework grade as a binary variable (completed or not), one cannot measure how much *Aplia* homework grade affects learning outcomes. This study is similar to that used by Trost & Salehi-Isfahani (2012) in that topic-specific exam grade of selected four chapters is used. In the meantime, this study is different in some important ways. First, *Learning Curve* is used as a pre-lecture homework. Not only completion but also the number of questions answered, and the accuracy of responses will be used. This study uses Difference in Difference (DID) estimation to see whether or not the difference on exam grade stems from *Learning Curve*. DID makes it possible to include all the chapter performances. Trost & Salehi-Isfahani (2012) control for student characteristics, including SAT scores. SAT score does not demonstrate a significant performance in upper level economics courses (Laband & Piette, 1995). This study instead, uses *GRIT* score (Duckworth, Peterson, Matthews, & Kelly, 2007). Motivation and the degree of GRIT are positively correlated with long-term goals (Duckworth et al., 2007). Furthermore, students who are more self-disciplined (or self-motivated) are more likely to succeed (Duckworth & Carlson, 2013; Heckman, Stixrud, & Urzua, 2006; Segal, 2012).

3. Methodology

3.1 The Courses

The study targets one face-to-face and two hybrid classes of the Principles of Macroeconomics course taught by the author at an urban university with a diverse student body. 57% of students are full time students and working full time. 86% of participants said that the course is required. The face-to-face course has two 75-minute lectures per week while the hybrid course has one 75-minute lecture per week. Each course had 120 enrolled students. All courses being taught by the same instructor, there was no professor bias. Both face-to-face and hybrid courses used a flipped pedagogic method. To prevent any disadvantage attributed to the lack of face-to-face time, instructional videos containing explanations of course material including examples and practice questions were made available. Each video is on average 10-minute long and is posted on the Learning Management System (LMS) of all courses.

3.2 Experiment Design

Students were randomly assigned to a group on the first day of class. Group A can get credit for *Learning Curve* activities related to the 2nd, 4th, 7th, and 9th chapters. Group B can get credit for *Learning Curve* activities related to the 3rd, 5th, 8th, and 10th chapters. Both groups get credit for *Learning Curve* activities related to the Aggregate Demand and Aggregate Supply chapter.

Learning Curve is an adaptive learning tool; when a student does not answer a question correctly, *Learning Curve* asks another question about the same concept. When a student takes time to answer, *Learning Curve* nudges her an opportunity to see a hint. After seeing a hint, the student receives a lower score than the score without seeing hints. Students have unlimited attempts to reach a target score set by the instructor for each chapter. Once the target score is reached, the student receives full credit. *Learning Curve* questions are pulled from a question bank that is selected by the instructor at the beginning of the semester so that only class relevant materials are used.

4. Data

The data consists of exam grades for each chapter and student characteristics are derived from survey and observed data from 132 students in the hybrid course and 96 students in the face-to-face course. The mode of the data is described as a sophomore female student who is taking more than 12 credit hours per semester with a full time job. This student took one high school economics course, but none from college yet. She is required to take the course and to study 2 hours per week outside of class with 4 visits to LMS. Her GRIT score is 2.6 out of 5.

5. Findings

5.1 Chapter-by-Chapter Analysis

This model uses DID estimation to estimate the impact of the adaptive learning tool, *Learning Curve* (*LC*), on the student learning outcome for each chapter, *Y,* measured by the percentage of the number of questions correctly answered in each chapter. Control variables are post-lecture homework, *HW*, and a control variable, *X*, which includes observed and surveyed student characteristics for student *i* and chapter *j*. *Group* is a binary variable taking the value 1 for group A and the value 0 for group B.

$$Y_{i,j} = \beta_1 + \beta_2 \times Group_{i,j} + \beta_3 \times LC_{i,j} + \beta_4 \times HW_{i,j} + \beta_5 \times X_{i,j} + u_j + \epsilon_{i,j}$$

Table 1 shows that the adaptive learning tool, *Learning Curve*, is not associated with a positive effect on student learning outcome in contrast to post-lecture homework. One point, or 5-percentage point, increase in post-lecture homework score is associated with an increase of 0.50% in midterm, and 0.66% in final exam. Hybrid courses have a lower grade in midterm by 0.38% than the face-to-face course, but not for final exam. Due to the limited face-to-face lecture time in hybrid courses, the adaptive learning tool might replace face-to-face lecture time; therefore the adaptive learning tool would improve SLO in the hybrid course. However, the adaptive learning tool did not improve SLO.

Table 1   Panel Analysis: Learning Curve on Midterm and Final

VARIABLES	(1) Midterm with all student characteristics	(2) Midterm with effort variables	(4) Final with all student characteristics	(6) Final with effort variables
LC	0.0008	0.0009*	0.0000	0.0002
	(0.001)	(0.000)	(0.000)	(0.000)
Post HW	0.0057***	0.0050***	0.0066***	0.0064***
	(0.002)	(0.001)	(0.001)	(0.001)
Hybrid	-0.3824***	-0.3736***	-0.0009	
	(0.032)	(0.019)	(0.025)	
Visit	0.0077***	0.0052***	0.0028***	0.0017**
	(0.001)	(0.001)	(0.001)	(0.001)
Duration	0.0474	0.0501	0.0376	0.0511*
	(0.044)	(0.042)	(0.026)	(0.026)
Group	0.0390*	0.0167	0.0677***	0.0424**
	(0.023)	(0.017)	(0.021)	(0.017)
Constant	0.6474***	0.5861***	0.6768***	0.5974***
	(0.087)	(0.030)	(0.078)	(0.016)
Observations	1,239	1,794	1,399	2,279
Number of id	140	227	140	228

Note: Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1

This paper hypothesizes that group A, who completed Learning curve of chapters assigned to only group A, would perform better on those chapters. We will call it *group A chapters* (respectively, *group B chapters*) those chapters assigned to group A (respectively, B).

Table 2 shows students' performance in midterm exam and final exam of group A chapters. The coefficient of interaction term between *LC* and *Group* shows that adaptive learning pre-lecture homework does not have a significant effect on midterm and final exam performance. Rather, post-lecture homework does. 10-point or 50-percentage point increase in post-lecture homework score is associated with a 5% to 6% increase of each chapter grades in exams.

Table 2   Learning Curve on Midterm and Final: Group A Chapters

VARIABLES	(1) Midterm with all student characteristics	(2) Midterm with effort variables	(3) Midterm with effort variables	(4) Final with all student characteristics	(5) Final with effort variables	(6) Final with effort variables
LC	0.0010	0.0011	0.0011*	0.0000	0.0004	0.0004
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
LC×Group	-0.0019	-0.0016	-0.0016	0.0003	-0.0004	-0.0004
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Group	0.0724	0.0565	0.0546	0.0495	0.0543*	0.0547*
	(0.051)	(0.044)	(0.044)	(0.034)	(0.028)	(0.028)
Post HW	0.0049**	0.0052***	0.0051***	0.0062***	0.0056***	0.0056***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Hybrid	-0.0189	-0.0174		-0.0009	0.0149	
	(0.036)	(0.023)		(0.025)	(0.017)	
Visit	-0.0015	-0.0019**	-0.0019**	-0.0000	0.0001	0.0001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Duration	0.0523**	0.0471**	0.0459**	0.0513***	0.0532***	0.0541***
	(0.023)	(0.022)	(0.022)	(0.019)	(0.019)	(0.019)
Constant	0.8306***	0.6374***	0.6265***	0.6897***	0.6082***	0.6166***
	(0.120)	(0.036)	(0.034)	(0.081)	(0.024)	(0.022)
Observations	280	454	454	560	912	912
Number of id	140	227	227	140	228	228

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

We should look at whether group A performs worse in group B chapters. Table 3 shows students' performance in group B chapters. There is no significant positive effect of Learning Curve on final exam performance. As was with group A chapters, post-lecture homework is associated with a positive and statistically significant relationship with exam performance in group B chapters as well. Group A still performs better in group B chapters on midterm (up to 22% better) and on final exam (up to 10% better). This might confirm that either the adaptive learning tool pre-lecture quiz does not improve exam performance or there are other unobserved effects. We will discuss this later in the paper. Hybrid courses have 6% lower grade in midterm of group B chapters. The same was not observed with group A chapters.

This study hypothesized that group A who completed adaptive learning tool for chapters assigned to group A would have better learning outcomes for those chapters, and group B would have better learning outcomes for group B chapters. Group A, who completed adaptive learning tool of assigned chapters, did perform better in the

exam on those chapters. However, this cannot be attributed to the adaptive learning tool as the interaction variable of adaptive learning tool and group is negative, although is not statistically significant. Post-lecture homework is a better predictor of midterm and final performances. It was confirmed that the adaptive learning tool is a good predictor of post-lecture homework performance, although the result is not reported here. Also the results state that group A did better in group B chapters, and it is not thanks to the adaptive learning tool as the interaction term between the adaptive learning tool and group is negative.

Table 3   Learning Curve on Midterm and Final Group B Chapters

VARIABLES	(1) Midterm	(2) Midterm	(3) Midterm	(4) Final	(5) Final	(6) Final
LC	0.0030	0.0045***	0.0046***	0.0016	0.0009	0.0009
	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
LC×Group	-0.0048	-0.0052***	-0.0052***	-0.0014	-0.0005	-0.0005
	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Group	0.2219*	0.1969***	0.1974***	0.1017**	0.0334	0.0337
	(0.117)	(0.065)	(0.063)	(0.049)	(0.033)	(0.033)
Post HW	0.0009	0.0039*	0.0041*	0.0034**	0.0015	0.0015
	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Hybrid	-0.0685*	-0.0453*		-0.0025	0.0058	
	(0.036)	(0.026)		(0.030)	(0.020)	
Visit	0.0014	0.0019	0.0016	0.0000	0.0007	0.0007
	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Duration	-0.1763	-0.6748	-0.6956	0.6597***	0.3335**	0.3340**
	(0.556)	(0.512)	(0.519)	(0.199)	(0.162)	(0.162)
Constant	0.5787***	0.4556***	0.4235***	0.5719***	0.6472***	0.6502***
	(0.178)	(0.065)	(0.062)	(0.104)	(0.034)	(0.032)
Observations	140	227	227	419	683	683
Number of id				140	228	228

Note: Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5.2 Learning Curve Analysis

We have seen that *Learning Curve* with pass/fail grade does not have a positive correlation with SLOs. However, this does not say much about the target score, the number of questions, or accuracy of students' responses.

As the target score is set higher, students have to correctly answer more questions than before, offering thereby more chances for students to be exposed to concepts prior to lecture. *Learning curve* allows students to choose to answer more questions after they reach the target score as well. The result shows that target score does not have a positive effect on SLO. Interestingly, the number of questions answered by students has a positive effect on midterm performance, however the magnitude is small; 0.1% higher grade. This reveals an interesting aspect of human behavior; when the target score is set higher, students are forced to answer more questions to reach it, which does not improve their exam performance. However, when students voluntarily choose to answer more questions, one has slightly higher exam performance, however not statistically significant. It is likely that motivated students might choose to answer more questions. Ironically, accuracy of learning curve responses does

not have any statistical significant effect on exam performance.

5.3 Pre-knowledge Comprehension

Aggregate demand is derived from the concept of Keynesian cross. One can test if the understanding of Keynesian cross would help in understanding the Aggregate Demand-Aggregate Supply model. Both group A and group B completed post lecture homework of the Chapter "Aggregate Demand and Aggregate Supply". *Learning Curve* activity on Keynesian Cross was made available to both group A and group B. However, only group B was required to complete the activity. We can test if group B has a better performance than group A in *Learning Curve*, post-lecture homework, and exams of Chapter of Aggregate Demand and Aggregate Supply.

Table 4 shows that group B did not necessarily perform better in Aggregate Demand and Aggregate Supply. However, regardless of the group assignment, those who completed *Learning Curve* of Keynesian cross performed better on post-lecture homework and midterm but not on final. This confirms that student's effort matters to a certain degree.

Table 4   Keynesian Cross on Aggregate Demand

VARIABLES	(1) HW ADAS_1	(2) HW ADAS_1	(3) HW ADAS_2	(4) HW ADAS_2	(5) Midterm ADAS	(6) Midterm ADAS	(7) Final ADAS	(8) Final ADAS
Group	-0.7471		-0.6986		0.0090		0.0139	
	(0.756)		(0.701)		(0.032)		(0.026)	
LC_Kynesian Cross		2.3260**		2.1072**		0.0711**		0.0276
		(0.906)		(0.830)		(0.032)		(0.030)
Hybrid	1.5261**	1.4573*	1.2703*	1.1813*	-0.0945***	-0.0938***	-0.0201	-0.0202
	(0.769)	(0.750)	(0.696)	(0.680)	(0.031)	(0.031)	(0.026)	(0.026)
Duration_ADAS	-22.2151	-15.5212	-27.0437	-20.7643	1.8140*	1.9566*	0.7561	0.7923
	(27.240)	(24.036)	(17.026)	(15.023)	(0.983)	(1.034)	(0.512)	(0.516)
Visit_ADAS	0.0326	0.0193	0.0380	0.0214	-0.0083**	-0.0090**	-0.0014	-0.0018
	(0.069)	(0.062)	(0.070)	(0.070)	(0.004)	(0.004)	(0.003)	(0.003)
Constant	14.8614***	12.8519***	14.5396***	12.7185***	0.5605***	0.5368***	0.4465***	0.4462***
	(0.799)	(1.050)	(0.725)	(0.930)	(0.064)	(0.058)	(0.048)	(0.044)
Observations	200	200	188	188	199	199	182	182
R-squared	0.185	0.204	0.138	0.176	0.309	0.316	0.382	0.381

Note: Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The hybrid course has a 9% lower grade in the exam on Aggregate Demand and Aggregate Supply. This chapter was the first chapter with diagrams in the semester. As hybrid courses have limited lecture time, students had limited exposure to visual examples of diagrams.

5.4 Priming Effect

Group was assigned randomly on the first day of class. However, group A has 4% higher grade on final exam than group B in Table 1. First chapter *Learning Curve* was available to both groups, although it was not for credit. The first credit assignment, *Learning Curve* of second chapter, was due on the second week of the semester, and only group A was required to complete it. This created an unintended consequence; a priming effect on group A; group A had to put the course at their higher priority than group B. The average of homework completion rate was higher for group B. However, 90% of group A completed first post-lecture homework, which was due 2nd week of

the semester, but only 83% of group B.

Furthermore, Table 5 shows the results of SLOs of students who completed *Learning Curve* of first and second chapter. Column (1) displays the results for students who completed first *Learning Curve*. As was expected, group A did not perform better. The same holds for students who completed second *Learning Curve* in column (3). Column (5) shows that there were no significant differences in SLOs for those who completed both first and second chapter of the Learning Curve. One can conclude that those students who start course assessments early in the semester tend to perform better. This effect is much larger in hybrid courses. In hybrid courses, group B performs worse than group A by 6%. However, among students who did not complete both *Learning Curve* of first and second chapter, group A records 13% higher final exam performance than group B.

Table 5   Priming Effect

VARIABLES	(1) Yes 1st LC Final	(2) No 1st LC Final	(3) Yes 2nd LC Final	(4) No 2nd LC Final	(5) Yes 1st & 2nd LC Final
Group	0.0265	0.0805***	0.0324	0.1313***	0.0256
	(0.020)	(0.029)	(0.020)	(0.044)	(0.022)
LC	0.0005	-0.0004	0.0002	0.0001	0.0005
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Post HW	0.0081***	0.0036***	0.0066***	0.0042**	0.0075***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Hybrid	0.0199	0.0278	0.0091	0.1343	0.0199
	(0.020)	(0.036)	(0.020)	(0.121)	(0.022)
Visit	0.0027***	-0.0001	0.0017**	0.0039**	0.0025**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Duration	0.0418	0.0954*	0.1208*	0.0230	0.1209*
	(0.029)	(0.057)	(0.066)	(0.031)	(0.067)
Constant	0.5408***	0.5842***	0.5728***	0.5097**	0.5460***
	(0.026)	(0.037)	(0.025)	(0.211)	(0.028)
Observations	1,569	710	1,779	370	1,399
Number of id	157	71	178	37	140

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

This result cannot distinguish if an early assignment nudges students, leading therefore to better performance, or if motivated students complete the assignment, leading therefore to better performance.

6. Conclusions

Claims that Adaptive Learning tools help students' comprehension and improve students' learning outcomes are unsubstantiated. This paper finds no positive statistical significant effect of adaptive learning tool as pre-lecture homework on exam outcomes. Adaptive learning tool is based on a mastery learning, which improves post-lecture homework performances, however has limitation, as it did not show any positive effect on exam outcomes.

Using Keynesian Cross and Aggregate Demand, this paper shows that pre-knowledge of the model is positively associated with understanding of the model. This paper also finds that target score or accuracy of adaptive learning tool does not have any statistically significant positive effect on SLOs. First assignment is used as a nudge as those students who completed the first homework performed better than those who did not. Both results show that student's effort is important, however, causality cannot be confirmed.

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