Live or Online Lectures: Evidence from Classroom Random Control Trials

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Introduction

The Budgetary constraints facing higher education has led to conversations about how we approach course delivery. Legislators and administrators often think on-line courses will save money, while still meeting student needs. As such, there has been an increase in research investigating the effects of different types of classroom technology. The research on the effectiveness of web-based course delivery is mixed. In this study, we employ a within-subjects random control trial experiment design to address the question of whether on-line lectures can be a substitute for live or in-class lectures. The order of the paper is a brief literature review, followed by the experimental design and the results, then some discussion and the conclusion.

Literature Review

Research on Lecture Capture Technology (LCT) has increased substantially over the past 15 years as technology has become easier to use and more readily available. Early on LCT was in the form of television usage. McConnell in a 1968 study observed the results from watching lectures via television on economic learning were insignificant. Since then, with the advent of on-line accessibility, podcasts (audio lectures), video casts and other types of LCT have been incorporated into our classrooms. Newton et.al. (2014) describes LCT as "the use of digital technology to capture elements of a live lecture in a variety of different ways, which are subsequently provided to the students in a digital video format" (p.32). Because of the diverse

types of LCT and ways of using it, comparisons of research studies are difficult. We concentrated on studies that incorporated the recording of live lectures and posting them on line for students to access.

Many of studies on LCT have been on attendance, but there are also studies on how students use LCT availability, the difficulty of the material, student ability, student performance, and gender differences. In their 2017 review of LCT studies, O'Callaghan, et.al. find the research on attendance is mixed. Even though the preponderance of studies do not support the argument that LCT can substitute for attendance, students who miss class occasionally find the availability of online LCT is advantageous.[1] For students who have a greater propensity to skip, A. Williams, et.al. (2012) show students using LCT as a substitute for live lectures performed better than those who did not use it at all. However, Jones and Olczak (2016) and Edwards and Clinton (2019) find the gains they receive from viewing the lectures online are not sufficient to offset the loss of knowledge from missing class.

The argument that the availability of online lectures substitute for class attendance, misses the benefits of using LCT to supplement live lectures. LCT provides students an opportunity to enhance their note taking, fill comprehension gaps, review for exams, and allow them to control the pace of their learning (Karnad 2014, Traphagan et.al. 2010). Bassili (2008), Brown and Liedholm (2002), and McCunn and Newton (2015) all note students tend to prefer live lectures and use the LCT to supplement them. Most of the studies we looked at indicate students who discovered LCT was a tool to be used in addition to the live lecture, performed better than those who just used it as a substitute for class attendance.[2]

Studies focused on gender differences in the usage of LCT, also find mixed results. Bassili (2008), Chen and Lin (2012) and McCunn and Newton (2015) report males are more likely to access LCT. They contend since males, on average, tend to miss more classes than females, they are more likely to believe lecture capture will provide them with enough information to be a substitute for live lectures. Whereas males were more likely to use LCT as a substitute for live lectures, several studies observe females using it as a complement to the live

[1] Brown and Liedholm 2002, Leadbeater, et.al. 2013, McCunn and Newton 2015, McKinney et.al 2009, Jones and Olczak 2016, Karnad 2014, O'Callaghan 2017, Wiese and Newton 2013 and Newton, et.al. 2014, and A. Williams, et.al. 2012.

[2] Bassili 2008, Brown and Liedholm 2002, McCunn and Newton 2015, Vajoczki, et.al. 2011, and A. E. Williams, et.al. 2016.

lectures[3]. Other studies show women take advantage of LCT more than males[4]. Bosshard and Chiang (2016) and Liedholm (2002) find females will choose LCT, if given the choice. They show female students find supplementary podcasts hold their attention longer and are more relevant than did the male students. According to Leadbeater, et.al. (2013) a benefit of LCT for females is the ability to take more expansive notes. McKinney, et.al. (2009) indicate students who took notes from LCT had significantly higher scores, and the greatest advantage went to those you took higher quality notes.

The difficulty of the material taught and the ability level of the students is another reason for differences in accessing LCT. Several studies refer to the idea of "Deep" learning and "Surface" learning[5]. "Deep" learning is internalizing the presented material, which involves higher levels of learning. "Surface" learning is low level learning such as rote memorization and reproducing facts (Wiese and Newton 2013). Taking a "Deep" approach entails more access to LCT as a supplemental tool for review. Additionally, when it comes to more complex or perceived difficult material, Owston et.al. (2011) find the number of accesses to LCT increases.

McCunn and Newton (2015) notice those taking a "Surface" approach tend to access LCT less, while Vajoczki et.al. (2011) find "surface" learners are more likely to use LCT as a substitute for attending class. O'Callaghan et.al. (2017), agree, LCT is better for "surface" learners, because they are able to use it to replace attending class. Conversely, Trenholm et.al. (2019) provide empirical evidence that LCT use may actually encourage more surface learning and, therefore, negatively affect student performance.

The ability of the student may help to explain this discrepancy. High ability students are less likely to need supplementary material to succeed on low level learning, and, as such, do not access LCT very often, if at all. High ability students have learned to use their study time more efficiently and only access LCT when necessary (Figlio, et.al. 2013, Owston et.al. 2011). Low ability students, though, did better when they used LCT regularly. They observed LCT helps them build their confidence, develop comprehension skills, and improve their note taking abilities, which helps them to succeed better in the course (Owston et.al. 2011). In contrast,

[3] Brady et.al. 2013, Chen and Lin 2012, McCunn and Newton 2015, Wiese and Newton 2013, and A. Williams, et.al. 2012.
[4] Bosshardt and Chiang 2016, O'Brien and Verma 2019, Pham 2010, Wiese and Newton 2013, Vajoczki, et.al. 2011, and A. E. Williams et.al. 2016.
[5] Bassili 2008, Brown and Liedholm 2002, McCunn and Newton 2015, O'Callaghan 2017, Trenholm et.al. 2019, Vajoczki et. al. 2010, Vajoczki et.al. 2011, A.E.Williams, et.al. 2016, and Wiese and Newton 2013.

Stroup et.al. (2012) report students in an introductory economics course with low GPAs earned lower grades in LC sections, than the low GPA students in the non-LC sections. This was not the case for high GPA students. Stroup et.al. go on to hypothesize that LCT provides low GPA students a false sense of security about using it to replace class attendance.

The $20 million question, though, is whether LCT helps students do better in their courses. The results on the effectiveness of LCT in the literature are mixed, although it appears access to LCT does no harm; and as such may be a good tool to add to the toolbox of improving student learning. In fact, even if the differences are insignificant, given the students positive views about the technology, they may become more engaged in the material presented. Additionally, there may be greater benefits for some students, especially students with dyslexia, those who are non-native English speakers, or anyone who needs more time to digest the course material (Kinash, et.al. 2015, Vajoczki, et.al.2011, A. E. Williams et.al. 2016)).

Brown and Liedholm (2002) compared live lectures with virtual/on-line courses and a hybrid of the two, with LCT being the bridge. Looking at gender, they determined females scored 5.7 percentage points lower than men in the live lecture section, but the difference was insignificant between the virtual and hybrid sections. They also saw the same results for black students - they did worse in the live course and the difference was insignificant between the hybrid and virtual course. In studying gender differences with LCT, Bosshardt and Chiang (2016) initially found insignificant results, but when they corrected for self-selection, females performed 0.35 standard deviations lower than males. Figlio, et.al. (2013) ascertained males, as well as Hispanics, do better with LCT, even though the overall average was insignificant. Moreover, Jones and Olczak (2016) noticed there were greater positive effects for students with poor backgrounds.

Interestingly, Inglis, as reported in Karnad (2014), saw those who preferred online delivery did worse than those who preferred live lectures. From this, they imply that online students are less motivated and use LCT to replace attendance. Additionally, Drouin (2014) finds LCT negatively affects both course participation and course performance. He compares two class sections, of which only one had access to LCT, and finds there were significantly more "nonparticipants" (attended fewer classes, completed less than half of the assignments) in the LC section. When he removed those students from the analysis, the difference in performance between the two sections disappeared.

There are some major problems with comparing these studies. The statistical methodologies used differ and, as such, lead to diverse outcomes. Coates, et.al. (2004) reported insignificant results, but, as with Bosshardt and Chiang (2016), when they controlled for sample selection, the online results were significantly worse. Additionally, what constituted LCT differed. Some studies used it as part of an online/ virtual course, others in a type of hybrid or flipped course. Furthermore, the time-frame varied from a full semester to just a couple of units. Our contribution to the literature is the use of a truly randomized control group of 230 students to examine whether the students in LC only sections performed better than the students in live lecture sections.

Experiment design

We follow the framed field experiment design as described by Harrison and List (2004). In particular, we impose an intervention on randomly assigned groups of students within the normal environment and structure of Principles of Microeconomics courses in a regional comprehensive university. An independent tenured Associate Professor of Economics lectured for 30 minutes covering two topics on two separate occasions in each of five course sections. Each section's lecture was recorded and almost immediately posted to the course's online learning management system. In each trial, one group of students could only consume the material via in-class lecture while the other group could only consume the material via LC video.

We randomly assigned students into two groups by the odd or even number of their student identification[6]. Precisely 230 students were assigned into the groups; 127 odd-numbered students and 103 even-numbered students. The first trial intervention covered monopsony, a relatively simple concept to understand at that point in the course schedule. The instructors had already taught monopoly and market power topics, so students were somewhat prepared for the material. For this trial, we allowed only the even-numbered students to attend the monopsony lecture. These students were prohibited from viewing the lecture online. The odd-numbered students could consume the lecture via LCT as often as they liked, but were not allowed to attend the live lecture. Two days later the students completed a ten-question multiple-choice quiz on the monopsony topic (see Appendix 1).

[6] The university assigns student ID numbers as they are enrolled following the simple formula: $Student_{i+1} = Student_i + 1$.

The second trial's lecture took place roughly one month later and covered uncertainty and risk, traditionally more difficult topics for students to understand and digest. In this trial, only the odd-numbered students could attend the live lecture while the even-numbered students viewed only the LCT video, but as often as they liked. Again, the students completed a ten-question multiple-choice quiz on the uncertainty topic two days later (see Appendix 2).

Results

While our primary aim is to test for any potential differences in assessment performance between consuming lectures in-class versus LCT, we also are interested in gender and ability differences across students that might explain performance variation by lecture delivery. Consequently, we collected demographic and preference information in surveys at the beginning and conclusion of the course and on the first and last days of the experiment. The summary statistics, along with the mean assessment scores, are posted in Table 1. These measures reflect the typical Principles of Microeconomics classroom at the university. The class is 36% female, roughly 10% non-white, and averages about 20 years of age. Most students work for pay and average 11 hours of work per week. Only 11% of students say they take "great" notes as opposed to "good" or "poor" notes, but a majority of students (64%) report they study more than once prior to assessments. Finally, the average ACT score and college GPA of respondents is 22.7 and 3.1, respectively.

Table 1 also reports the mean assessment scores. The trial 1 (monopsony) quiz average score is nearly 2.5 out of 10 points higher than the trial 2 (uncertainty) quiz average. These results confirm our suspicion that the uncertainty material would be more difficult for students to grasp. This contrast in difficulty allows us to provide some evidence of whether LCT affects assessment scores differently depending on the difficulty of lecture material.

Table 2 provides the mean quiz scores by lecture consumption type within each trial. In trial 1 the in-class students performed better (0.36 points) than students consuming the video lectures, but in trial 2 the roles were reversed and larger in magnitude (0.61 points). Using the entire sample, t-tests comparing the mean score of in-class students with the mean score of LC students confirm that the trial 2 LC students indeed performed statistically significantly better than the trial 2 in-class students did. The trial 1 difference was not statistically significant.

As an explanation for this contradictory result, we first speculated that perhaps one of the randomly assigned groups was simply a better cohort, first consuming the lecture in class and then consuming it online. After comparing the two cohorts' GPA and ACT scores, we find the two groups are nearly identical in ability. The trial 1 LC (in-class) students had a slightly higher (lower) GPA of 3.048 (3.015) and a slightly lower (higher) ACT score of 22.65 (22.83). Thus, we can conclude the randomly assigned groups do not exhibit substantial differences in ability that might explain the results.

While t-test comparisons of unconditional means across randomly assigned groups offer compelling evidence, we go further in identifying potential sources of performance differences using ordinary least squares regressions including the demographic characteristics listed in Table 1 as controls. Columns 1 and 2 in Table 3 present the results. First, the LC students performed significantly worse in the trial 1 assessment. The magnitude is not trivial. The deficiency is a full regression adjusted 0.62 difference in scores. In other words, the effect of consuming the online LC video in trial 1 is roughly equivalent to the effect of having a 0.49-point lower GPA (2.61 vs. the average 3.10 GPA).

The trial 2 result presented in Column 2 of Table 3 is diametrically opposite. With this more difficult material, the LC students performed statistically significantly better by 0.77 of a point than the live lecture students. This is equivalent to having a 0.58 point higher GPA (3.68 vs. 3.10). The difference in results by material difficulty is interesting. While we are uncertain of the mechanism, the results increase the ambiguity associated with how well LCT might serve as substitutes for live lectures. Although the literature reflects this ambiguity, our framed field experiment approach coupled with testing differences in material difficulty offer fresh and new perspectives to the current literature.

Discussion

The LCT vs. live lecture literature contains a variety of results describing differences in how student gender might predict assessment outcomes. Generally, the literature shows men do better with LCT and women worse with in-class lectures. Brown and Liedholm (2002) and Bosshard and Chiang (2016) found females scored significantly lower than men in live lectures, which implies we should expect males to do worse in LC courses. McCunn and Newton (2015)

and Chen and Lin (2012), though, found LCT helped males to catch up from low attendance, but the gains were not sufficient to make up for missing class.

Our random control trials suggest otherwise. First, female student performance is entirely independent of lecture consumption method. Regardless of course material difficulty, female students consuming live lectures score equally as well on assessments as female students consuming LC videos. These are shown by statistically insignificant t-tests in the female sample columns of Table 2, and in regression-adjusted coefficients in columns 3 and 4 of Table 3 and in column 2 of Table 4. Female student performance is not impacted by the availability of LCT.

Male students, however, performed far differently depending upon material difficulty and lecture consumption method. With the easier material (monopsony), in-class male students substantially outperformed the LC male students by nearly 1 point on the quiz (out of 10). Yet with the more difficult material (uncertainty), the in-class male students performed substantially worse than the LC male students by more than 1 assessment point (out of 10). These statistically significant results are presented in the male sample columns of Table 2, columns 5 and 6 of Table 3 and column 3 of Table 4.

These results on the difficulty of the material are contrary to the literature. Brown and Liedholm (2002), among others, find students prefer live presentations when the material is perceived complex and in-class students do significantly better on the complex material. However, A. E. Williams, et.al. (2016) note LCT is not an effective tool for low level learning, which means we can hypothesize LCT is more effective for high level learning. Owston, et.al. (2011) find when the material is difficult, students access LCT more often. Whereas we cannot provide a mechanism explaining these results, we offer new evidence supporting the ambiguity present within the literature.

Our data provides additional information regarding students' preferences and behavior toward online LCT consumption that may point to potential mechanisms. First, female students are better at taking notes and study "deeply" more often than male students, who are more likely to be "surface" studiers, so they can replace attending class (Vajoczk et al. 2011). This is a potential explanation for the equivalent performance of female students consuming live lectures vs. LC videos. In particular, better quality notes coupled with more frequent studying potentially mitigates any effect that lecture delivery, or material difficulty, might have on student assessment performance. This studying and note-taking gender disparity is evident in columns 2

and 3 of Table 1. The proportion of female students that suggest they take great notes is roughly ten percentage points higher than male students, and female students are also more likely to write a greater quantity of notes. Moreover, female students are about 15 percentage points more likely than male students to say they study their notes more than once before every assessment.

Second, if male students are typically worse at taking notes and studying, then the lecture delivery method and material difficulty may have outsized effects for them. With easier material, an in-class lecture may require more engagement and attention by students, whereas a LC video might bore students and encourage them to pay less attention. This implies that male students would perform worse after watching an online video relative to a live lecture. Female students, on the other hand, have good study and note-taking habits, which mitigates this relationship. Regarding more difficult material in-class male students would be lost without high quality notes to study, whereas confused LC male students could watch the lecture a number of times to grasp the material better. McKinney, et.al. 2009 study indicates students who take more and better notes do significantly better than those who do note. Thus, the difference in study habits and note-taking quality between genders may explain the phenomenon our data uncovers. Indeed, Table 5 presents summary statistics suggesting that the male students consuming the LC video on the difficult material have better study and note-taking habits than the students consuming the difficult material in class.

Other observations that may be worth mentioning…

- Male students think they are far more tech savvy than female students
- At the beginning of the semester, only about 7% of the students thought they would learn more from video lectures, but at the end of the semester, roughly 21% thought they learned more from watching video lectures.
- Nearly 1/3 of students prefer to watch lectures via LCT rather than in class. Males prefer video lectures more by about 5 percentage points.
- ACT scores only positively affect assessment scores on the difficult quiz. This is intriguing. ACT scores arguably measure natural problem solving and critical thinking ability, so when students are lost on tough material, students with natural ability perform substantially better. However, on easy material, having higher natural ability does not make much of a difference.

- It may be important to mention that female students never perform worse than male students do (insignificantly worse on the first quiz but insignificantly better on the second quiz).
- The relatively small sample sizes may be a concern, especially in the gender subsamples. As a potential solution, we double them by pooling the data and standardizing the quiz scores such that coefficient estimates are now in terms of standard deviations from the mean quiz score. In these estimations we cluster the standard errors by student. The estimates presented in Table 4.
- We can also take more advantage of the end survey's questions.

Conclusions

Most studies on lecture capture focus on attendance, use as a supplement or a complement to live lectures, or the performance of students over a specific period of time. Our study differs in that we compare each individual student performance with and without access to any form of lecture capture.[7]

Unfortunately, our data did not allow us to investigate some of the areas involving access, attendance, and uses of LCT. After collecting the data, we were not able to know how many times students accessed the video, which limited the results we could compare. Due to the design of our study, we are unable to test how students are using LC videos, especially in regards to use as a substitute or complement to the live lectures. Future research needs to fill in some of these gaps, especially on how students can use technology to improve their course outcomes.

Given the mixed results in the literature and in our results, we do not find many cases where students actually do worse when on-line video lecture is available. However, students like using the technology, as noted in Basilli (2008), Wiese, and Newton (2013), among others, and may become more interested in the subject because of the on-line video lecture.

[7] Our study's focus on gender effects and material difficulty do not necessitate controlling for fixed effects.

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Table 1: **Summary Statistics. Means with standard deviations in parentheses.**

Variable description	Obs.	Whole sample	Female students	Male students
LC 1: assigned to view lecture online in trial 1	230	0.535	0.512	0.555
		(0.500)	(0.503)	(0.499)
LC 2: assigned to view lecture online in trial 2	230	0.465	0.488	0.445
		(0.500)	(0.503)	(0.499)
Quiz 1: score on trial 1 quiz (out of 10)	208	7.952	7.893	8.008
		(1.958)	(2.057)	(1.887)
Quiz 2: score on trial 2 quiz (out of 10)	210	5.481	5.676	5.388
		(2.170)	(2.127)	(2.186)
Female: = 1 if student is a woman and 0 otherwise	228	0.360	-----	-----
		(0.481)	-----	-----
Non-white: = 1 if student's race is not white and 0 otherwise	228	0.105	0.159	0.075
		(0.308)	(0.367)	(0.265)
Age: age of student in years	227	20.251	20.238	20.267
		(2.936)	(1.891)	(3.388)
GPA: cumulative college grade point average at start of the semester (out of 4)	225	3.145	3.110	2.985
		(1.727)	(0.485)	(0.440)
ACT: student composite collegiate entrance exam score (out of 36)	213	22.732	22.493	22.851
		(3.140)	(3.509)	(2.954)
Hours: number of hours per week student works for pay	226	11.280	15.975	8.681
		(11.703)	(12.645)	(10.355)
Sophomore: = 1 if student is a college sophomore and 0 otherwise	230	0.548	0.512	0.575
		(0.499)	(0.503)	(0.496)
Grant: = 1 if student receives a need-based tuition grant and 0 otherwise	230	0.826	0.854	0.822
		(0.380)	(0.356)	(0.384)
Comp. Pref.: = 1 if student prefers to take notes on a computer and 0 otherwise	230	0.078	0.049	0.096
		(0.269)	(0.217)	(0.295)
Great notes: = 1 if student self-assesses note-taking skill as "great" and 0 otherwise	230	0.109	0.171	0.075
		(0.312)	(0.379)	(0.265)
Good notes: = 1 if student self-assesses note-taking skill as "good" and 0 otherwise	230	0.804	0.793	0.822
		(0.398)	(0.408)	(0.384)

All vocal notes: = 1 if student writes everything professor says in notes and 0 otherwise	230	0.139	0.195	0.110
		(0.347)	(0.399)	(0.313)
All board notes: = 1 if student writes everything in notes that professor writes on board and 0 otherwise	230	0.748	0.841	0.705
		(0.435)	(0.367)	(0.457)
All math notes: = 1 if student copies all graphs and mathematical steps in notes and 0 otherwise	230	0.691	0.732	0.678
		(0.463)	(0.446)	(0.469)
Study often: = 1 if student consults notes more than once prior to every assessment and 0 otherwise	230	0.643	0.744	0.596
		(0.480)	(0.439)	(0.492)
Useful notes: = 1 if student says notes are very useful for performing well in courses and 0 otherwise	230	0.561	0.549	0.575
		(0.497)	(0.501)	(0.496)
Savvy: = 1 if student rates tech savviness as advanced or highly advanced for age group and otherwise	228	0.386	0.256	0.459
		(0.488)	(0.439)	(0.500)
Stream: = 1 if student usually watches TV and/or movies using streaming services and 0 otherwise	230	0.665	0.695	0.644
		(0.473)	(0.463)	(0.481)
Will learn more from video: = 1 if student will learn more from watching video lectures and 0 otherwise	227	0.066	0.061	0.069
		(0.249)	(0.241)	(0.254)
Learned more from video: = 1 if student learned more from video lectures and 0 otherwise (end survey)	203	0.207	0.211	0.200
		(0.406)	(0.411)	(0.402)
Prefer video: = 1 if student prefers to consume lectures via video and 0 otherwise (end survey)	203	0.305	0.282	0.323
		(0.462)	(0.453)	(0.469)

Table 2: **Quiz scores by group with means and standard deviations in parentheses (two-sample t-tests)**

	Trial 1		Trial 2	
Variable	**LC group (ODDS)**	**In-class group (EVENS)**	**LC group (ODDS)**	**In-class group (EVENS)**
Quiz Score (Out of 10)	7.786 (1.919)	8.146 (1.995)	5.813 (2.104)	5.202 (2.195)
Observations	112	96	96	114

Unpaired Two-sample T-Tests. Ho: mean(in-class) - mean(LC) = 0.

t-statistic
(p-value in parentheses)
{number of observations in brackets}

Whole sample		**Female sample**		**Male sample**	
Quiz 1	Quiz 2	Quiz 1	Quiz 2	Quiz 1	Quiz 2
1.325 (0.187) {208}	-2.047** (0.042) {210}	0.082 (0.935) {75}	0.397 (0.693) {74}	1.836* (0.069) {131}	-2.956*** (0.004) {134}

Note: ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. All t-tests assume equal variances.

Table 3: OLS regressions

	Whole sample		Female sample		Male sample	
	Quiz 1	**Quiz 2**	**Quiz 1**	**Quiz 2**	**Quiz 1**	**Quiz 2**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
LC	-0.616**	0.766***	-0.377	-0.400	-0.955***	1.323***
	(-2.397)	(2.594)	(-0.704)	(-0.758)	(-3.089)	(3.754)
Female	-0.241	0.213	-----	-----	-----	-----
	(-0.676)	(0.607)	-----	-----	-----	-----
Non-white	0.522	0.483	1.212*	0.361	-0.812	-0.815
	(0.821)	(1.043)	(1.658)	(0.511)	(-1.269)	(-1.258)
Age	0.092	0.105	0.537*	0.709**	0.029	0.084
	(0.807)	(1.181)	(1.679)	(2.013)	(0.362)	(1.014)
ACT	0.046	0.200***	0.191**	0.296***	0.014	0.199***
	(0.934)	(3.725)	(2.404)	(3.190)	(0.216)	(2.876)
GPA	1.270***	1.324***	1.651***	1.645	0.988**	1.506**
	(3.013)	(2.931)	(2.807)	(1.515)	(2.020)	(2.511)
Hours	0.001	-0.003	-0.006	-0.056**	-0.007	0.010
	(0.068)	(-0.208)	(-0.340)	(-2.201)	(-0.365)	(0.598)
Sophomore	0.510	0.012	0.723	0.554	1.137***	-0.007
	(1.361)	(0.032)	(1.129)	(0.652)	(2.785)	(-0.014)
Grant	0.106	-0.252	0.467	0.473	0.127	-0.335
	(0.298)	(-0.642)	(0.575)	(0.515)	(0.313)	(-0.702)
Comp. Preference	-1.512**	-1.620***	0.652	-0.416	-3.200***	-1.600**
	(-2.051)	(-2.585)	(0.474)	(-0.235)	(-3.528)	(-2.144)
Great notes	0.053	0.559	4.937***	-0.897	-1.079	0.322
	(0.063)	(0.746)	(4.580)	(-0.606)	(-1.396)	(0.339)
Good notes	-0.308	-0.120	4.864***	-0.866	-0.999*	-0.002
	(-0.421)	(-0.200)	(4.343)	(-0.599)	(-1.756)	(-0.003)
All vocal notes	0.009	-0.294	-0.458	-0.461	0.221	0.057
	(0.027)	(-0.700)	(-0.910)	(-0.713)	(0.446)	(0.102)
All board notes	0.611*	0.958***	0.129	1.175	0.645	0.721*
	(1.713)	(2.784)	(0.213)	(1.414)	(1.595)	(1.654)
All math notes	0.181	-0.466	0.697	-0.541	0.085	-0.374
	(0.581)	(-1.326)	(1.246)	(-0.784)	(0.229)	(-0.970)
Study often	-0.089	-0.287	-0.339	-0.050	0.418	-0.682*
	(-0.265)	(-0.889)	(-0.654)	(-0.069)	(0.998)	(-1.657)
Useful notes	0.542*	-0.004	0.847	-0.590	0.250	0.094
	(1.715)	(-0.012)	(1.495)	(-0.909)	(0.650)	(0.216)
Savvy	-0.423	-0.141	-0.663	0.188	-0.365	-0.219

	(-1.453)	(-0.446)	(-0.955)	(0.246)	(-1.186)	(-0.561)
Stream	-0.091	0.115	-1.125***	-1.543**	0.501	0.605
	(-0.320)	(0.366)	(-2.787)	(-2.123)	(1.401)	(1.642)
Will learn more from video	1.136***	0.303	0.869	-0.848	1.913***	1.206*
	(2.603)	(0.505)	(1.021)	(-0.673)	(4.085)	(1.941)
Learned more from video	0.405	-0.477	0.060	-0.406	1.082**	0.193
	(0.895)	(-1.172)	(0.083)	(-0.498)	(2.355)	(0.385)
Prefer video	-0.056	0.182	0.098	-0.019	-0.388	-0.180
	(-0.146)	(0.437)	(0.129)	(-0.024)	(-0.813)	(-0.326)
Constant	0.420	-5.052**	-17.255**	-16.326*	3.075	-6.047**
	(0.158)	(-2.134)	(-2.154)	(-1.804)	(1.347)	(-2.418)
Adj. R-squared	0.187	0.218	0.470	0.327	0.254	0.250
Observations	179	186	62	63	117	123
Notes: ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. Estimations control for 5 course sections. Heteroskedasticity-robust standard errors are used.						

Table 4: Pooled OLS regressions on standardized quiz scores

	Whole sample	**Female sample**	**Male sample**
	(1)	**(2)**	**(3)**
LC	-0.279**	-0.030	-0.459***
	(-2.173)	(-0.140)	(-2.913)
Difficult subject	-0.323***	0.082	-0.565***
	(-2.609)	(0.378)	(-3.750)
LC x difficult subject	0.655***	0.030	1.063***
	(3.429)	(0.092)	(4.963)
Female	0.003	-----	-----
	(0.025)	-----	-----
Constant	-4.164***	-10.995***	-3.651***
	(-4.616)	(-3.542)	(-4.821)
Adj. R-squared	0.201	0.389	0.241
Observations	363	123	240
Notes: ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. Heteroskedasticity-robust standard errors are clustered at the student level. All controls listed in Table 3 are included. Estimations control for 5 course sections.			

Table 5: Comparison of select summary characteristics of male sample by lecture method

	Male sample	
	Trial 2 In class	Trial 2 LCT
Great notes: = 1 if student self-assesses note-taking skill as "great" and 0 otherwise	0.064 (0.247)	0.098 (0.300)
Good notes: = 1 if student self-assesses note-taking skill as "good" and 0 otherwise	0.808 (0.397)	0.869 (0.340)
Poor notes: = 1 if student self-assesses note-taking skill as "poor" and 0 otherwise	0.128 (0.336)	0.033 (0.180)
Study often: = 1 if student consults notes more than once prior to every assessment and 0 otherwise	0.551 (0.501)	0.656 (0.479)
Online learning: = 1 if student learned equal or more from videos vs. in-class lectures	0.486 (0.503)	0.556 (0.502)
Observations	78	61

Appendix 1: Monopsony assessment with correct answers in bold

1) The labor supply curve facing a purely competitive employer is _____ whereas the labor supply curve facing a monopsonist is _____.
   A) upward sloping; horizontal
   B) downward sloping; vertical
   C) vertical; upward sloping
   D) horizontal; upward sloping

2) The economic term for a firm that is the sole buyer in a market is:
   A) monopsonist.
   B) monopolist.
   C) perfect competitor.
   D) oligopolist.

3) Which of the following is a characteristic of a labor market that is a monopsony?
   A) The type of labor available is perfectly mobile.
   B) The supply curve for labor lies above the marginal cost of labor curve of the firm.
   C) The wage rate the firm must pay workers is lower than the marginal cost of hiring workers.
   D) The firm's employment is a small portion of the total market employment of that type of labor.

4) Other things equal, the monopsonistic employer will pay a:
   A) lower wage rate and hire fewer workers than will a purely competitive market.
   B) higher wage rate but hire fewer workers than will a purely competitive market.
   C) lower wage rate but hire a larger number of workers than will a purely competitive market.
   D) higher wage rate and hire a larger number of workers than will a purely competitive market.

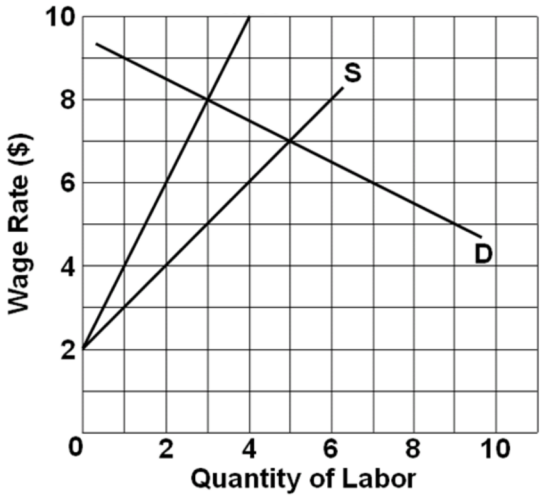
5) A monopsonist can hire 5 workers at $10 per hour, but if it wants to instead hire 6 workers, it would have to pay each worker $12 per hour. What is the marginal cost of the 6^{th} worker?
   A) $12
   B) $10
   C) $24
   D) $22

6) Which of the following is most likely to be an example of monopsony?
   A) The market for fast-food workers in a large summer resort town.
   B) The market for construction workers in Las Vegas.
   C) The market for major league baseball players.
   D) The market for retail sales clerks in a major city.

7) In a monopsony labor market, the wage is _____ the marginal cost of hiring a worker, but in a perfectly competitive labor market for a firm, the wage is _____ the marginal cost of hiring a worker.

A) lower than; equal to
B) higher than; equal to
C) equal to; higher than
D) equal to; lower than

Figure 1



8) Refer to the labor market diagram in Figure 1 where *D* is the labor demand curve, *S* is the labor supply curve, and MC_L is the marginal cost of labor curve. If this labor market were relevant to an individual firm, we could conclude that the firm is:

A) a pure competitor in the hire of labor.
B) a monopsonist in the hire of labor.
C) selling its product in an imperfectly competitive market.
D) selling its product in a purely competitive market.

9) Refer to the labor market diagram in Figure 1 where *D* is the labor demand curve, *S* is the labor supply curve, and MC_L is the marginal cost of labor curve. If this were a purely competitive labor market, the equilibrium wage rate and level of employment would be:

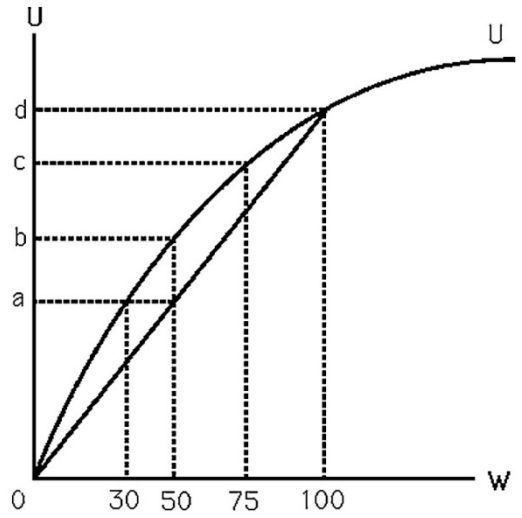
A) $5 and 3 respectively.
B) $6 and 4 respectively.
C) $7 and 5 respectively.
D) $8 and 3 respectively.

10) Refer to the labor market diagram in Figure 1 where *D* is the labor demand curve, *S* is the labor supply curve, and MC_L is the marginal cost of labor curve. If this were a monopsonistic labor market, the equilibrium wage rate and employment level would be:

A) $5 and 3 respectively.
B) $6 and 4 respectively.
C) $7 and 5 respectively.
D) $8 and 3 respectively.

Appendix 2: Uncertainty assessment with correct answers in bold

1) Expected value represents
   A) the actual outcome one expects to receive.
   B) the average of all outcomes one would receive if one undertook a risky event many times.
   C) the outcome one receives if he or she makes the correct decision.
   D) the outcome that is most likely to occur.

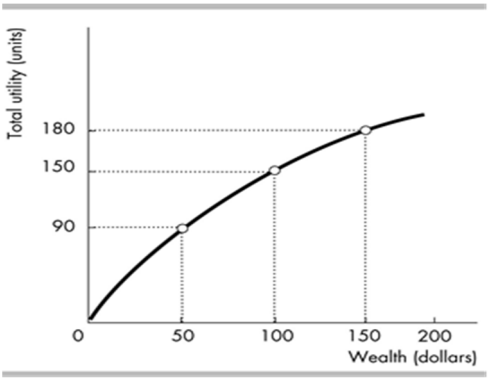


2) The above figure shows Bob's utility function. He currently has $100 of wealth, but there is a 50% chance that it could all be stolen and he would have $0 of wealth. Bob's expected utility is
   A) a.
   B) b.
   C) c.
   D) d.

3) The above figure shows Bob's utility function. He currently has $100 of wealth, but there is a 50% chance that it could all be stolen and he would have $0 of wealth. Living with this risk gives Bob the same expected utility as if there was no chance of theft and his wealth was
   A) $0.
   B) $20.
   C) $30.
   D) $50.

4) Diminishing marginal utility of wealth leads to risk aversion because at a given level of wealth a dollar gained
A) is worth more in additional utility than a dollar lost is worth in decreased utility.
B) is worth less in additional utility than a dollar lost is worth in decreased utility.
C) is worth as much in additional utility as a dollar lost is worth in decreased utility.
D) does not add to total utility.

5) You took a summer job as a salesperson in a shoe store with the knowledge that you will either make $2,000 or $3,500 with probabilities 0.4 and 0.6 respectively. What is your expected income for the summer job?
A) $2,000
B) $3,000
C) $5,000
D) $2,900



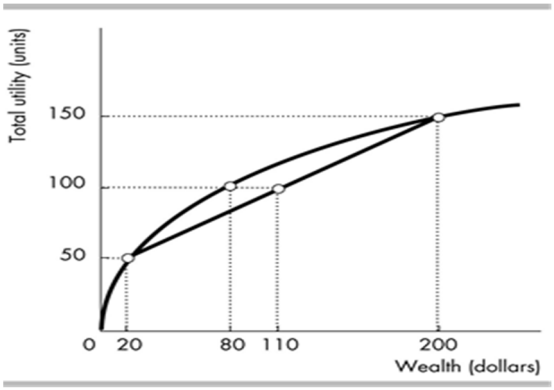
6) Linda's utility of wealth curve is given in the above figure. Option A gives Linda $100 for sure. Option B gives Linda $50 half the time and $150 half the time. Linda's expected utility of option A
A) is greater than the expected utility of option B.
B) is the same as the expected utility of option B.
C) is less than the expected utility of option B.
D) could be either greater or less than the expected utility of option B.

7) Nick has two job offers, one as a financial planner and one as an economist for a regional bank. The income that Nick would expect to earn as a financial planner depends on how effective he is in getting clients. He estimates that he would receive either $80,000 and a utility of 75, with a probability of 50%, or he would earn $30,000 and a utility of 35, with a probability of 50%. The economist job would pay $45,000 per year with 100% certainty and has a utility of 55. To maximize his expected utility, which job should Nick take?
A) Nick is indifferent between the two jobs.
B) Nick is better off if he takes the economist job.
C) Nick is better off if he takes the job of financial planner.
D) Nick should look around for another job.

8) Catherine is risk-averse. When faced with a choice between a certain level of wealth and a gamble (an uncertain level of wealth), she will
A) always prefer the gamble.
B) always prefer the certain level of wealth.
C) prefer the gamble if the expected utility from it is higher than the utility from the certain level of wealth.
D) prefer the certain level of wealth if the expected utility from the gamble is higher than the utility of the certain level of wealth.

Wealth (thousands of dollars)	Total utility
0	0
10	50
20	90
30	120
40	140

9) Use the table above to answer the question. If Susan works as a real estate agent, there is a 50 percent chance that she will earn $10,000 per year and a 50 percent chance that she will earn $30,000 per year. Susan's expected utility if she works as a real estate agent is most likely to be
A) 170.
B) 85.
C) 20.
D) 90.



10) The above figure shows how an individual evaluates a bet in which he or she has a 50% probability of receiving $20 and a 50% probability of receiving $200. The individual would be indifferent between
A) $110 with certainty or the expected value of the bet.
B) $80 with certainty or the expected value of the bet.
C) $200 with certainty or the expected value of the bet.
D) $20 with certainty or the expected value of the bet.