ABSTRACT

This study examines student achievement in a large introductory Business Economics class in which a face-to-face approach was supplemented with two types of materials available electronically. These materials consisted of files of written matter (including the instructor’s lecture notes, PowerPoint slides, exercises, solutions and practice tests) available to download from Blackboard, and video recordings of lectures available through MediaSite. Controlling for student experience and ability, no significant effect on final examination performance was found from their accessing of MediaSite. However, there was a significant positive relationship between the number of times Blackboard materials were accessed and exam mark. There was also an important gender difference in results in favour of males, especially on the multiple choice part of the exam.

Keywords: pedagogy, information technology, student performance, gender difference.

JEL classifications: A2, A22

1. INTRODUCTION

The use of internet technology in large classes at universities has increased considerably in the last few years. When surveyed on their
preferences, students tend to the view that the more alternative resources that are available to them the better. From the side of the suppliers of educational services, attitudes to new technology tend to polarise around two very different views. Driven by student demand, university administrators continually add to and upgrade technology often without undertaking any cost-benefit analysis of outcomes. One of the most recent manifestations of this is the rush from some universities to be involved in the provision of Massive Open Online Courses (MOOCs) without any clear analysis of the budgetary or educational implications. On the other hand, many faculty worry about the potential implications for student behaviour, educational standards and intellectual property.

The really important questions, however, do not centre on attitudes but on outcomes in terms of student achievement. Here, the evidence is sparser. This paper proposes to make a contribution to providing evidence on how the availability of electronic access to material to support traditional face-to-face teaching and learning affects student final results.

Evidence is presented from a natural experiment in a large introductory university class in Business Economics in which students had access both to extensive materials written to complement the lectures and to video recordings of the lectures themselves. Controlling for student experience and ability, access statistics provided by the same system that facilitates access to the course materials are used to address the question of how such access relates to performance on the final examination. The findings indicate a strong positive association between access of the written materials, but not the video materials, and exam results and also point to improved ways to gather further, more detailed evidence from a natural setting without the need for controlled experiments.

Of course, any natural experiment such as this can only add a small amount of incremental evidence. Yet there are a number of practical and ethical difficulties surrounding the design of a broader or more controlled study. For example, one possible way to try to collect more evidence would be simultaneously to study a number of different courses across different disciplines. However, such an approach would entail a uniformity of approach to course design which is unlikely to exist, even within a single academic unit of a single institution. Nor is such imposition of uniformity likely to be educationally sound. To
compare outcomes in the same course over time would rely on strictly limiting course changes in a way that stands in opposition to the typical pedagogical desire for improvement. Further, controlled studies assigning different students to different treatments creates ethical difficulties when the outcome of assessment carries real implications for students. Nevertheless, it must be conceded that any one study cannot provide conclusive evidence and must inevitably be subject to limitations. In the present case, for example, one could no doubt raise concerns about whether generalisation from the context of a regional Australian setting, with a relatively large proportion of time-poor students from lower socio-economic backgrounds, is possible. Accumulation of evidence from a number of such studies is, however, one way to begin to address the practical difficulties of other approaches. A good deal of the literature reviewed here is in fact from single-discipline, single-institution studies and the discipline and institution is cited, if known.

The remainder of this paper is structured as follows. Section 2 briefly reviews how the current study fits within the existing literature. Section 3 details the methods used, section 4 presents the results, while section 5 concludes.

2. LITERATURE REVIEW

In spite of the possibility of electronic delivery of not only written notes but video recordings of lectures, many instructors resist the full use of such technology, some expressing very strong views. Taylor (2007) clearly articulates this when he says, “Lectures are the backbone of modern university education. Students must listen attentively … while capturing the intellectual structure to the knowledge being proffered.” He sets such a high store on the skill of listening and note-taking that he seems not to have considered making his own notes available to the students and he appears to resent recording of his lectures. Harrp (2008) responds with the diametrically opposed view, suggesting that “one of the most common reactions they [students] have while taking notes in class is … ‘What did he/she just say?’” In other words, whatever the value of the traditional lecture, many students in many subjects require more learning opportunities.

Chang (2007) undertook a systematic study of instructor opinion with respect to the audio recording of lectures at the University of Melbourne. A number of concerns were raised, including lecture attendance and engagement with learning in general. When student
opinion is canvassed, there tends to be positive support for the
availability of online material; for example, see Davis, Connolly &
Linfield (2009) (for evidence from the University of Leeds, UK) and
Karakostas, Demetriadis & Ragazou (2010) (for evidence from the
University of Thessalonika, Greece). Of course, even careful surveys of
opinion are just that, opinion, and provide no evidence on performance.
Heilesen (2010), who reviews the literature from studies in a number of
disciplines and schools, suggests that, as with many new technologies,
podcasting (by which he means making available audio or video
recording of classes) has been met with bold claims for its efficacy but,
as yet, little evaluation of its benefits in relation to its costs. Its adoption
has been driven by perceived student demand and by the concern of
administrators to keep up with the competition. Goffe & Sosin (2005),
in reviewing some of the evidence, also across a number of disciplines
and schools, report positive results from the use of technology with
respect to student attitudes. When it comes to the effect on student
performance, the evidence is more mixed.

Owston, Lupshenyuk & Wideman (2011) contribute an extensive
review of the literature on the availability of recordings of lectures,
from both theoretical and empirical perspectives. Theoretically, of
course, the availability of a wider range of resources should suit a wider
range of learning styles, with the recording of lectures particularly
suited to those who prefer listening as opposed to reading. The
empirical evidence is broken up into that which reports on support for
student learning and that which notes effects on student performance.
The former, not unexpectedly, indicates overwhelming student support
for the availability of recordings. Of particular note is a perceived
reduction in stress and anxiety when students know that they can re-
visit material in whole or in part. The evidence on student performance
is more equivocal, with some studies showing performance improving
with access to recordings and others finding no significant effect. A
sample of the most recent evidence includes Grabe & Christopherson
(2005), Savage (2009), Wieling & Hofman, (2010) and Owston,
Lupshenyuk & Wideman’s (2011) own study.

Grabe & Christopherson (2005) (Psychology, University of North
Dakota, USA) consider how the use of lecture notes made available to
download affects student performance. In their study two types of notes
were made available online: Outline Notes, the brief PowerPoint type
summaries as used in lectures, and Complete Notes, which were taken
by a professional note taker who attended lectures. Since students were surveyed on how and when they used the notes, it was possible to address a number of different research questions but, of most relevance here, is the finding of significant but only weak correlations between note access and examination performance. Savage (2009) (Economics, University of Colorado, Boulder, USA) conducted a controlled experiment in an intermediate-level course. He assigned students at random to control and test groups. The test group had access to video of lectures, while the control group did not. Although the test group scored on average two percentage points higher on the final examination, the difference was not statistically significant. In contrast, Wieling & Hofman, (2010) (Law, University of Groningen, the Netherlands) did find a significant positive effect on student grades from accessing online lectures as a supplement to face-to-face teaching. Their study had the advantage of information on both online lectures viewed and attendance at face-to-face lectures, although the latter was self-reported. In fact, quite a number of the additional control variables, such as those for learning style and prior expectations were based on the use of questionnaires. Additional materials provided to students were available only in the form of online multiple-choice tests with feedback and students were randomly assigned either to a group that had access to these materials or to one that did not. Surprisingly, no positive effect of access to the tests was found but use of the online lectures was associated with improved grades, with the effect being more pronounced for students who attended fewer face-to-face lectures. Owston, Lupshenyuk & Wideman (2011) (Health, York University, Canada) actually found that those students who viewed recordings of the lectures once a month or less often performed better than those who were frequent viewers. Higher-achieving students also adopted a more discriminating approach in their viewing, fast-forwarding to parts they wanted to see again, whereas lower achievers tended to watch whole lectures.

3. METHODS
The context of the present study is a large introductory class in Business Economics. It is a single-semester introductory course combining both microeconomics and macroeconomics and is compulsory for all undergraduate students in a School of Business. Currently a major in economics is not offered so that all of the students taking this course have the intention of majoring in another discipline, such as accounting,
general management, human resource management, information technology, marketing, property development or tourism. The subject is also compulsory for intending majors in journalism and engineering. A student needs no pre-requisites to enrol in the course.

The purpose of this paper is to offer some evidence on how the use of materials provided online affects student results. The use of the material made available is a measure of student effort. Other influences on student performance include the student’s previous experience, general ability and, teachers would like to think, teacher input, so that one can conceptually think of a student’s performance on a course as measured by some “mark” as given by:

\[
\text{Mark} = f (\text{Experience}, \text{Ability}, \text{Effort}, \text{Teaching})
\]  

(1)

The more accurately the characteristics that affect the mark can be measured, the better we are likely to be able to explain student marks. In practice, any such approach will be affected by data availability and, therefore, to some degree by omitted variable bias. As already discussed, ethical considerations preclude any sort of controlled experiment, but it is possible to take advantage of the information that happens to be collected regarding every student for the administration of the course and, incidentally, by the online courseware management system in a regression analysis. The next sub-section discusses the specifics of the choices of what to measure for both the dependent and independent variables.

In terms of the dependent variable, naturally, we have available all of the marks, each expressed as a percentage, gained by each student across a number of internal assessment items as well as on the final exam. The final exam score, \( \text{exampc} \), can be broken down into two equally weighted components, the first a score on multiple choice items, \( \text{mcpc} \), and the second the score on written questions, \( \text{wrtnpc} \), requiring a combination of answers to closed technical as well as more open-ended questions. Many of these questions were similar to those in tutorial exercises. In addition, we have student scores on an essay, \( \text{essaypc} \), a mid-semester test, \( \text{midpc} \), and the combined score on two short multiple-choice tests, \( \text{mctestspc} \). The focus of the econometric analysis which follows, and the chosen dependent variable, is the total final exam score (\( \text{exampc} \)). This is chosen over the total mark on the course since the latter includes scores on tests and essays graded before the end of the course and therefore, at least to some extent, occurring at
the same time or even before some of the measures to be used as independent variables, creating an endogeneity problem in that a student may, for example, respond to a poor test result by increasing usage of the online materials.

There are two possible measures of student experience available. These are the student’s age and the number of points attempted up to and including the current semester, units. Each semester length course is worth 12 points. A student typically enrols in subjects worth 48 points per semester. Age is a simple measure of maturity and, up to a point, one would expect performance to improve with maturity. If a diminishing rather than linear effect of age is expected, this can be allowed for by including the square of age, agesq. Whatever a student’s age, and some students do first enrol at a relatively mature age, there is a presumed positive effect of familiarity with the university environment. The variable units is included to capture this effect.

Most of the students enrolled in this course are in their first semester of university study and access to their previous academic background is not available. In fact, the only accessible measure of general ability is each student’s grade point average (GPA) up to and including the courses taken in the same semester as the Economics course. To avoid simply explaining, in part, the score on Economics by itself, each student’s GPA without the Economics course was calculated. The variable gpaexecon is the cumulative sum of the student’s grade points (less the final score on Economics) divided by the number of points taken (less 12 points, being the points-value of the Economics course). Unfortunately, the difficulty remains that a student’s value on this variable is subject to how he or she allocates effort across Economics and other subjects taken in the same semester. Any given student’s GPA to date will be affected by the mix of compulsory and optional subjects taken so far and the student’s interest in and aptitude for these subjects. Students in their first semester of study are likely to be less certain of their ultimate major than students in later years of study and to be taking a greater proportion of compulsory courses. Nevertheless, gpaexecon is the best proxy we have for a measure of general academic ability.

University policy mandates that no contribution to final grade can be awarded for attendance or participation in classes. Consequently, attendance is not monitored. In large lecture streams this would in any case be impracticable. Given the lack of attendance requirements, student access to electronically available material is the only aspect of
student effort that is monitored as the information is automatically collected. At the end of the course, two measures of how many times each student had accessed the materials were available: \( \text{accessBB} \) is the number of times the student accessed written materials available via Blackboard, and \( \text{accessMS} \) is a measure of how many times each student had accessed video recordings of the lectures via MediaSite.

Extensive material was made available to students on Blackboard, consisting of the following items for each of 11 modules of the course:

a) A copy of the instructor’s notes, which was available at least a week before the relevant class in both WORD and PDF formats. It was written in simpler language than the prescribed textbook and contained any diagrams and tables to be used in the class. These notes form a very complete record of the material covered so that students need not focus on note-taking in class.

b) A copy of the instructor’s PowerPoint presentation. This differed from the notes in that it was much less detailed but it did contain animated diagrams, unlike the notes. The presentations were also made available at least a week before the relevant class.

c) A set of tutorial exercises for the module, also available in advance.

d) A set of suggested answers for the tutorial exercises. These were made available only after the last tutorial session in a given week.

e) A ten-item practice multiple-choice test based on the topics covered in the module. The tests could be attempted online as often as desired and/or printed out.

As well as the material accessible in this way, the lecture was also recorded once a week, always in the third of three lecture streams. The recordings were made available on MediaSite. The recording consists of audio, together with video in a split-screen format with the PowerPoint slides as they are used in class. The camera typically remains in a fixed position throughout the lecture, showing the front part of the lecture theatre. On a few occasions the instructor altered the camera position to point at a screen showing the output from a document camera on which worked examples were presented.

Neither of the measures of student access of materials is a perfect measure of actual usage of these materials. For example, a student
might download from Blackboard, every week of the course, all of the instructor’s notes, all of the tutorial exercises and practice tests and then never read any of them. It is also possible that a student who is struggling in some way with the use of the technology makes more repeated attempts to access the material with some pointless attempts adding to that student’s value of accessBB. In the case of MediaSite, it is impossible to tell how much, if any, of a given lecture a student watched on the occasion of any particular access, nor if the student skipped only to a few pieces of interest or watched from beginning to end. Further, it is possible that there might have been technical difficulties that might have caused multiple accesses of the same material. Notwithstanding these limitations, the two access measures are the only ones available and, moreover, if one had more information available, the construction of more valid access measures from that information might well be difficult.

There is no measurable variation in the teaching input to student performance. The method of delivery consists of a two-hour lecture session and a one-hour tutorial session in each week of the semester. The same instructor teaches three different lecture streams, two in a large lecture theatre with a capacity of around 300 and one smaller group on a separate campus in a room with a capacity of less than 30. There are five tutors employed to take the tutorials, which have group sizes of around 20. The different tutors are therefore the main potential varying input on the teaching side. Students are assigned to a tutorial group by a computer timetabling program but, since there are absolutely no attendance requirements, there is a considerable tendency for students to attend at a different time than the one assigned, either frequently or on occasion if their other commitments change. In addition, since one of the tutors left half-way through the semester and her classes were re-assigned to others, it is not really possible to measure a tutor effect.

We also know the gender of each student. Given previous evidence (Siegfried 1979, Greene 1997, Opstad & Fallan 2010) of the possible existence of a gender difference in performance in courses in Economics, a dummy variable, sex, which takes the value 0 for males and 1 for females was added to the regression equation. The preponderance of the previous evidence suggests that males, on average, perform better than females, in introductory economics
courses, more especially on assessments based on objective multiple-choice items.

The following equation, where $i$ indexes over students and $\varepsilon_i$ is an error term, is the basis for the regression analysis:

$$
\text{exampc}_i = a_0 + a_1\text{sex}_i + a_2\text{age}_i + a_3\text{agesq}_i + a_4\text{units}_i
+ a_5\text{gpaexecon}_i + a_6\text{accessBB}_i + a_7\text{accessMS}_i + \varepsilon_i
$$

(2)

Given previous evidence, one might expect the coefficient on $\text{sex}$ to be negative. It is hypothesised that the coefficients on $\text{age}$ and $\text{agesq}$ are positive and negative, respectively, with the turning point of the implied quadratic relationship with $\text{exampc}$ within the range of ages in the sample. The coefficients on both $\text{units}$ and $\text{gpaexecon}$ are expected to be positive. If these control variables perform as expected and the fit of the equation is reasonable, the results of estimating this equation will provide evidence on the statistical significance and practical importance of the student effort variables, $\text{accessBB}$ and $\text{accessMS}$.

4. DATA

Complete data were available on 460 students who completed the final exam. Those students who were enrolled but did not complete the final exam or who were permitted to do a deferred exam (at a later date) were excluded from the analysis.

48% of the students were female and 52% male. Their ages ranged from 18 to 55 with an average of nearly 22 years, although the modal age is 18 years, which is also the minimum age. The mean number of units attempted up to and including the current semester of study is just over 96, which is equivalent to about two semesters of full-time study. One student had studied only this Economics course and therefore, having no value of $\text{gpaexecon}$, was excluded from the regression analysis so that the sample size for the regression analysis is 459. There was a wide variation in the values of $\text{units}$, which is indicative of the fact that, although the course is compulsory for many students, they have a fairly free choice of when they attempt the subject.

Given the range of material that was made available on Blackboard, the mean number of times (28.5) this material was accessed seems surprisingly low. There is also considerable variability with a few students never using the material and some doing so many times; the maximum was 146. With the exception of the practice multiple-choice tests, the Blackboard materials are, in a sense, accessible by going to
class. The lecture notes form the basis of the material discussed in the weekly two-hour lecture, the PowerPoint slides are projected during the lecture and the exercises form the basis of the weekly one-hour tutorial. Therefore, a student who had no computer access of any sort could participate in the course in a way that would have been commonplace 20 years ago. Physical attendance at classes and use of Blackboard can be seen as substitutes. However, it is clear, from direct observation of students who attend regularly, that it is more typical for the two to be seen as complementary. Some students print out notes and/or slides and add their own annotations during class, some use laptops and type additional notes into the files and a few have even been observed simply to listen only, making no attempt to take any notes of their own.

As expected, since only recordings of the lectures are available on MediaSite, the average usage (14.7) is much lower than Blackboard, although there are a few very high access numbers, with 93 the maximum. To a student who never attends class, MediaSite is clearly a substitute and this well may be the case for students who are ill. Since there are very few students who never accessed MediaSite and, from casual conversation with some students, it is clear to the author that some students see lectures and videos of the lectures as complements. This is especially the case for those who prefer to listen rather than read.

When the raw data are broken down by sex, there are some interesting differences. Although the age distributions are similar, males seem to have slightly more experience as measured by courses taken, while females have a higher GPA. Both of these factors indicate the importance of such controls when analysing performance on the course. Table 1 reports gender differences on the effort variables and student outcomes on assessment items.

The mean number of times that females access both Blackboard (30.75) and MediaSite (15.23) is higher than the means for males (26.32 and 14.31, respectively). There seems to be little difference between males and females on the written part of the exam but, when it comes to multiple-choice, males perform better by nearly six percentage points. The pattern is the same on assessment items undertaken during the semester, with males performing better on the two short multiple-choice tests, by almost four percentage points, but with little difference between the sexes evident on the mid-semester test requiring written answers. On the prepared essay, females outperform males by about
Table 1: Effort Variables and Scores by Sex

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sex</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>accessBB</td>
<td>male</td>
<td>26.32</td>
<td>1.043</td>
<td>(24.27, 28.36)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>30.75</td>
<td>1.416</td>
<td>(27.97, 33.54)</td>
</tr>
<tr>
<td>accessMS</td>
<td>male</td>
<td>14.31</td>
<td>0.6546</td>
<td>(13.02, 15.60)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>15.23</td>
<td>0.7356</td>
<td>(13.79, 16.68)</td>
</tr>
<tr>
<td>exampc</td>
<td>male</td>
<td>53.87</td>
<td>0.9754</td>
<td>(51.96, 55.79)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>50.88</td>
<td>0.9847</td>
<td>(48.94, 52.81)</td>
</tr>
<tr>
<td>mcpc</td>
<td>male</td>
<td>66.34</td>
<td>1.031</td>
<td>(64.32, 68.37)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>60.81</td>
<td>1.121</td>
<td>(58.60, 63.01)</td>
</tr>
<tr>
<td>wrtnpc</td>
<td>male</td>
<td>41.40</td>
<td>1.067</td>
<td>(39.31, 43.50)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>41.40</td>
<td>1.043</td>
<td>(39.35, 43.45)</td>
</tr>
<tr>
<td>essaypc</td>
<td>male</td>
<td>59.58</td>
<td>1.292</td>
<td>(57.04, 62.12)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>63.63</td>
<td>1.339</td>
<td>(60.99, 66.26)</td>
</tr>
<tr>
<td>midtermpc</td>
<td>male</td>
<td>69.62</td>
<td>1.087</td>
<td>(67.48, 71.75)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>70.11</td>
<td>1.135</td>
<td>(67.88, 72.34)</td>
</tr>
<tr>
<td>mctestspc</td>
<td>male</td>
<td>73.89</td>
<td>0.9623</td>
<td>(72.00, 75.78)</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>70.06</td>
<td>1.088</td>
<td>(67.92, 72.20)</td>
</tr>
</tbody>
</table>

four percentage points. These differences have clear implications for the final course outcomes. If there is indeed a sex-linked difference in performance on different types of assessment items, then the weighting on these items will affect the relative performance of males and females.

5. RESULTS
Table 2 presents the results of running an OLS regression on equation (2) above. Tests for heteroskedasticity consistently rejected the null of constant variance. The $p$ values as reported are therefore all corrected for heteroskedasticity. This made no difference to the conclusions. The model reported in Table 2 explains 47.22% of the variation in the overall exam mark, with an adjusted $R$-squared of 0.4640. Given the measurement limitations inherent in many of the explanatory variables, this suggests that the model explains a reasonable proportion of the variation in exam scores. The adjusted $R$-squared is, of course, not directly comparable with other studies since their models differ from
The coefficients of all of the explanatory variables except accessMS, are highly statistically significant. The constant term in the regression is not statistically significant, but note that, if it were, its negative value does not represent a possible score as the minimum age in the sample is 18 years and other independent variables, too, have positive minimum values.

There is possibly an issue with multi-collinearity, but inefficiency in the estimates does not appear to be a major problem. There is almost certainly a problem with omitted variables, as in any empirical work. Indeed, Ramsey-reset tests formally suggest an omitted variables issue. However, we are simply constrained by the data available. If the coefficients are biased by the omission of relevant variables then these would most likely relate to the imperfectly captured measures of experience and ability. Nevertheless, the results suggest quite distinctly different effects of the two variables of interest, accessBB and accessMS, on student performance.

Comparing two students, one female and one male, identical on the other factors we have measured, we see that the female would score about 5.5 percentage points lower than the male. On a traditional A+ to C- nine-grade pass scale, this would amount, in most cases, to one full grade. As hypothesised above, this significantly negative coefficient on sex is consistent with the majority of previous findings.

The coefficients of age and agesq imply that increasing age improves one’s grade up to a point. The implied turning point is between 37 and 38 years of age, well within the sample range of 18 to 55 years. An
additional year of maturity, *ceteris paribus*, adds between 1.25 and 1.05 percentage points to one’s mark between the ages of 18 and 21 while, by around 30 years of age, an additional year is worth only half a percentage point.

The number of other courses taken, which tries to measure adaptation to the university system, also adds to one’s mark. A typical course is worth 12 units and a full-time load is traditionally 8 courses in one year, or 96 units. The point estimate of the coefficient of *units* therefore implies a gain of just over 2.5 percentage points in this course per year of university experience.

An increase of 1 on *gpaexecon* is associated with scoring more than 6 percentage points higher on this course. An increase of 1 on GPA is equivalent to an increase of 12% in the average percentage score over the other courses taken. Given the wide range of disciplines represented in the calculation of this measure of ability, this seems a plausible average effect across students with varied interests and prior and concurrent study.

As the number of times a student accesses *Blackboard* materials, *accessBB*, increases, so does his or her grade. The effect of just one more download is naturally small, but the differences in download behaviour in the sample are large. At the lower quartile of the distribution, an individual accesses the materials only 16 times, but at the upper quartile 37 times. This entails an implied difference in marks of nearly 2 percentage points.

Although the reported coefficient on *accessMS* is positive, it is not statistically significantly different from zero. It would appear that the number of times a student accessed the lecture videos had no significant impact on his or her final examination result.

6. DISCUSSION

The focus of interest in this study is the impact of access of electronically available material on final exam marks. In the context of what is a natural rather than a controlled experiment, it has been possible to use reasonable proxy variables to control for student experience and ability. Moreover, these variables have been found to relate to final exam results in the way expected, with the estimates of their coefficients having the correct signs in the regression analysis, being statistically significant and also of sensible magnitudes.

An analysis was undertaken of the results for the multiple-choice and written parts of the examination separately and the findings remained
qualitatively similar. It is notable, however, that the negative coefficient on the dummy for female was considerably larger for the multiple-choice, representing a difference of more than 8 percentage points. The implied turning points for age remained in a tight range between 37 and 39 with the value slightly higher on the written section than for the multiple-choice. The significance and magnitudes of the variables for the number of units taken and grade point average remained quantitatively very similar, although the $p$-value for units was only 0.08 in the case of mcpc.

Table 3 summarises the findings of how access of the materials relates to performance on the final examination and its two components: the multiple-choice items and the questions requiring written answers. The Blackboard materials are those that most clearly complement lecture attendance and it is the use of these (accessBB) that is shown to be positively associated with success in the course. This is particularly the case for the multiple-choice part of the exam with the magnitude of the coefficient of accessBB higher when considering just the multiple-choice score in isolation (0.1105 as opposed to 0.08673). Since practice multiple choice tests form a part of the Blackboard material, this is not surprising.

Table 3: Effects of Accessing Materials on Components of Final Exam Score

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Dependent Variable</th>
<th>exampc</th>
<th>mcpc</th>
<th>wrtnpc</th>
</tr>
</thead>
<tbody>
<tr>
<td>accessBB</td>
<td></td>
<td>0.08673</td>
<td>0.1105</td>
<td>0.0749</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.012)</td>
<td>(0.003)</td>
<td>(0.071)</td>
</tr>
<tr>
<td>accessMS</td>
<td></td>
<td>0.01203</td>
<td>-0.03131</td>
<td>0.01084</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.848)</td>
<td>(0.662)</td>
<td>(0.887)</td>
</tr>
</tbody>
</table>

Note: $p$-values in parentheses

Accessing video recordings of the lecture cannot be proven as useful, yet their availability seems to do no harm. For the written part of the exam, the point estimate of the coefficient on accessMS is positive while, for the multiple-choice part, it is negative. In neither case does it come even close to statistical significance at conventional levels. The failure to find an association may be because the two most likely groups to access videos are those who scarcely engage on-campus at all (and
who, *ceteris paribus*, do badly) and those who obsessively engage with every sort of material (and who, *ceteris paribus*, do well).

7. CONCLUSION

However much value one places on the traditional teaching format, including especially the idea that there is a value in attending to lecture material and simultaneously taking notes, the evidence presented here is that supplementary material, in whatever form, on average enhances student performance or, at least, does not hinder it. Naturally, the evidence here is context specific, relating to a specific course, designed in a specific way in a specific discipline and in a specific institutional context.

There are very real difficulties in studying the issue at hand in any broader context. For example, even in this course, a process of ongoing review has already meant that a good deal of the material previously only made available on *Blackboard* has been duplicated in the form of a printed study guide. This was done at the suggestion of tutorial staff and has proven surprisingly popular with students who one might have supposed were “digital natives.”

The sort of natural experiment used here is a way of accumulating, one course at a time, incremental evidence, while avoiding both ethical difficulties and interference with evolutionary course design. In gathering future evidence, while it might be interesting to ask students directly for their views, their behaviour and its relationship to results is the real question. To be able to analyse this relationship further, it would be worthwhile in future to set up the online materials in a way that would allow a more detailed breakdown of what was accessed, as well as when and by whom with a view to pinpointing the materials of most value to students. Given that the aim is to raise performance, such information would be valuable in two ways. First, teacher effort could be directed in the most effective way and, second, students could be explicitly told which study strategies appear to be most effective.

REFERENCES


