Which online learning resources do undergraduate economics students value and does their use improve academic attainment? A comparison and revealed preferences from before and during the Covid pandemic.

Abstract

The rapid shift to online learning during the Covid-19 pandemic led to widespread migration to online / blended delivery across UK Higher Education. This has prompted renewed interest in identifying the features of virtual learning environments (VLEs) which students value and are most helpful in academic development and attainment. Using the experience of delivery on an undergraduate module both before and after the introduction of an online delivery model, we use a revealed preference framework to analyse the influence of cognitive load on the value students attach to VLE features in combination with other learning resources. We also use regression analysis to examine which learning resources are crucial to attainment. Our findings suggests that students avoid cognitive overload by being selective in their use of learning resources. They showed a greater preference for both familiar and passive learning resources like lectures, lecture recordings and seminars in both learning environments. Students exhibited a lower preference for active VLE features - multiple-choice quizzes, open-ended questions and discussion forums. Nonetheless, use of open-ended questions along with lecture recordings and lecture slides had a significantly positive impact on academic attainment in the online learning environment. This supports instrumentalism in the use of these resources. Students were more selective in developing deeper understanding using online open-ended questions. Our results imply that module designers need to accept that such resources will be used more selectively. However, they should still be provided to encourage active, deeper learning.

Key Words: Virtual learning environments; recorded lectures; revealed preference; academic attainment.

JEL Classification Codes: A20; A22; D12; I21; I23

1. Introduction

The move to online learning for many students in the face of the Covid 19 pandemic in 2020/2021 led to a great expansion in the use of online resources for learning. Much of this involved the incorporation of more features of virtual learning environments (VLE) in the mix of learning resources. Many universities are seeking to accelerate the use of such features as part of degree study. Therefore, it is timely to analyse the employment of VLE features in economics education.

This paper adds to the extensive literature on student preferences for VLE features. Much of this work involves surveys of students to identify the value they place on the features offered on VLEs. The studies indicate that on-demand lecture recordings, collaborative tools and opportunities to receive individual feedback are most valued (see Limniou and Smith, 2010; Lyndon and Hale, 2014; Hamutoglu et al., 2020).

Our contribution is analysing students' use of VLE features in combination and as part of the wider mix of learning resources used on a module in the context of the cognitive load theory of multimedia learning (Paas et al., 2003)[1]. It would be anticipated that learning resources including VLE features would be expected to be used by students in a complementary manner to develop and deepen knowledge and understanding. However, cognitive load theory proposes that students may not engage with all the activities available because they are not able to integrate the information channelled through various learning resources – they experience cognitive overload. To avoid this, students may use a subset of resources available - the subset they find most valuable in learning.

There is a large literature including but not restricted to Economics that considers consumers' demand for a product or service on the basis of their willingness to pay. However, there are challenges in designing focus groups and/or surveys to determine accurately consumers' willingness to pay or their valuation of a good or service. An alternative approach to determining the extent to which consumers value a good or service is to observe their demand or use of it. This is known as the revealed preference approach. This has been adopted by limited research in analysing the value students place on recorded lectures (see Elliott and Neal, 2016). We adopt a

[1] Throughout the paper cognitive load theory of multimedia will be referred to as cognitive load theory.

similar revealed preference approach in this paper. The learning resources students engage with provides a good indication of the value they attach to those in learning. As part of our analysis, we compare students' use of module-level resources in two different learning environments - a learning environment with predominantly face-to-face delivery and one with online delivery. In doing so, we analyse how VLE features were used in each of the learning environments in combination with other resources. Further, we assess how the use of existing VLE features changed following the migration to the online learning environment and how new VLE resources were used.

We follow up the above analysis by adding to the literature investigating the factors which contribute to students' success on a module, considering students' engagement with various VLE features in combination with the wider mix of learning resources. It is hoped that the analysis will guide academics on the VLE features they make available to students in the future, through better knowledge regarding which features students find complementary to the wider mix of learning resources.

Our results offer support for the cognitive load theory of multimedia. Students appear to manage their cognitive load by being selective in their use of learning resources in both learning environments. All the resources, including VLE features, exhibited the full range of use. While students' use of passive resources which promoted shallow learning was more widespread, they were more selective in their use of the online open-ended questions which facilitated deeper learning. The selection was determined by the requirements of the assessment. Our regression results indicate that use of the VLE lecture recordings, slide files and open-ended questions had a significantly positive impact on academic attainment only in the online learning environment.

The structure of the remainder of the paper is as follows. In Section 2 a review of relevant literature to date is provided. Section 3 explains the empirical methods to be used. Section 4 presents and discusses the results of the analysis. Section 5 offers conclusions.

2. Literature Review

Virtual Learning Environments (VLEs) are web-based systems that enable students to interact with teachers and classmates, access learning resources anytime, anywhere and use cutting-edge Information and Communication Technology (ICT) (Bergen et al., 2012). There is an extensive literature on the features which should be included on a VLE. Using longitudinal survey evidence, Graven et al., (2006) recommended that module handbooks, contact information for staff, access to previous modules, assessment information and further reading should be included. Reed and Watmough (2015) quote evidence from the National Student Survey which indicate that students wanted recorded lectures, timely and improved feedback and faster communication with staff. Naveh et al. (2010) propose that content completeness, content currency, ease of navigation, ease of access, and communication are important aspects of a VLE to facilitate use. Chua and Montalbo (2014) also indicate content and communication as important but also encourage greater interactivity in the learner interface. Consequently, along with developments in ICT, the role of VLEs in learning has become increasingly prominent (Walker et al., 2014). VLEs have expanded to include multiple features such as lecture recordings, additional reading, discussion forums and interactive quizzes. The expansion was accelerated during the Covid pandemic.

The Cognitive Load Theory of Multimedia Learning (Paas et al., 2003) proposes that the human brain has a limited capacity for processing information through auditory and visual channels. Early studies of the impact of VLEs expressed concern that the proliferation of VLE features can be distracting and produce an adverse effect on student learning (Mayer and Moreno, 2002; Paas et al., 2003; Sweller, 2004). In this context, students may be selective in their use of VLE features to avoid cognitive overload. Consequently, they identify those which they find most beneficial for their learning, particularly in preparation for assessments. Therefore, this present study is timely, investigating which VLE features students find most valuable in their learning. The findings can help guide tutors in tailoring the mix of learning resources appropriately.

Already, there is an extensive literature on the features of VLEs that students (and teachers) most value. Mogus et al. (2012) produced a review of the early findings of

this literature. The majority of studies use surveys to gauge students' perception of the value of VLE features to support their learning. Heaton-Shrestha et al. (2009) highlight that VLEs gives students greater control of their learning (even if the students do not associate a VLE with greater learning flexibility). This finding is supported by Lyndon and Hale (2014). Within these broad statements about the benefits of VLEs, survey evidence indicates the types of features which students prefer. Both Limniou and Smith (2010) and Lyndon and Hale (2014) find that students particularly value collaborative tools and opportunities to receive individual feedback via VLEs. Meanwhile, Hamutoglu et al. (2020) find that students most value the access to lecture recordings and key concept films that VLEs provide on-demand. However, they find that students do not value discussion forums and chat tools. In summary, the evidence suggests that students are selective in the value they attach to the features of VLEs which is consistent with Cognitive Load Theory.

There is similarly a broad literature on the benefits and potential pitfalls associated with lecture recordings specifically: see Elliott and Neal (2016) for a discussion of this literature. Crucially, rather than using stated preferences from surveys, Elliott and Neal (2016) use a revealed preference approach to assess how undergraduate students on a core Economics module value on-demand lecture recording technology as a learning resource. Students' use of lecture recordings indicated that they were highly valued. It complemented the face-to-face event, with students viewing segments they found difficult to understand first time when attending the lecture. Further, there were waves of viewing activity just before assessment points, thus indicating that students used recorded lectures during revision. This is consistent with the benefits of flexibility and autonomy of VLEs highlighted by other studies (see Heaton-Shrestha et al., 2009). Only a few other papers are known similarly to adopt this revealed preference approach in the context of determining the value students place on lecture capture technology (see Chandra, 2007 and Andrews et al., 2013)

Existing work has analysed students' use of VLE features with little reference to how they complement other learning resources within a module. VLE features should complement each other as well as other learning resources including live lectures, seminars and independent study. These resources should be used in a sequenced, complementary manner progressively to develop and deepen students' knowledge and understanding, leading to higher levels of attainment. However, as the evidence

from surveys cited above suggests, students do not value all the learning resources offered. This indicates some sort of discernment, with students selecting a subset. This paper will extend the literature by using a revealed preference approach to analyse students' use of all learning resources in a module. In doing so, the work will investigate the influence of cognitive load on the patterns of use. Various patterns of use may indicate underlying explanations for limiting cognitive load. Firstly, students may be instrumental in their use of resources, with a focus on shallow rather than deeper learning (Marton and Säljö', 1976). We propose they will use a subset which they think is sufficient to pass an assessment. We propose that this explanation will be revealed by a preference for features which support shallow learning. Secondly, students may be used to live, synchronous classes throughout their time in education and prefer these familiar learning resources compared to new, unfamiliar VLE features. Finally, the sequence in which resources are presented may influence the pattern of use. Attempts to limit cognitive load may induce sequential bias where students use resources cued early in the learning sequence more than those cued later (Mantonakis et al., 2009). In the analysis, the paper will assess the influence of cognitive load through the following research questions:

1) What is the pattern of use of module level learning resources revealed in the two different learning environments (face-to-face versus online)?
2) How did engagement with learning resources, particularly VLE features, change following the migration to online learning?

Another strand of literature focuses on estimating the impact of VLE features on student learning, typically measured by student performance with controls for individual student characteristics. Some studies analyse the impact of overall VLE use on students' academic performance on a module. For instance, Calafiore and Damianov (2011) consider the impact of time spent on a VLE on student academic performance for several online Economics / Finance modules. Controlling for student characteristics, they conclude that both student grade point average (GPA) and time spent studying in the VLE have a positive, significant effect on final module performance. Similarly, Mogus et al. (2012) find a positive correlation between students use of VLE features and marks attained. More recently, Dascalu et al. (2021) find that students' engagement with VLE module content is significantly, positively associated with their performance. As in the current analysis, that study compared

students' use of VLE resources in the academic year directly pre-COVID and in the first academic year with COVID restrictions. Use of VLE features in the year with restrictions was more significantly associated with better academic performance.

Several other studies analyse the impact of the use of specific VLE features on academic performance. Both Flores and Savage (2007) and Savage (2009) identify a positive correlation between watching recorded lectures and student performance. Chen and Lin (2012) find that watching recorded lectures increased students' performance on a microeconomics module by up to 4%, controlling for other factors. Their results also show evidence of the benefits associated with the flexibility that VLEs permit. Watching recorded lectures in the week before an examination had a significantly positive impact on performance of between 3 and 5%. This may indicate evidence of instrumentalism with recorded lectures being used for last minute 'cramming'.

Meanwhile, Moffat and Robinson (2015) consider the provision of multiple-choice revision quizzes via a VLE in an economics module. They conclude that students' engagement with these quizzes is not significantly related to their final examination performance, urging caution in directing students to the use of such resources in case this results in a substitution away from other revision activities that may have greater, positive impact on student performance.

The research to date either analyse general use of VLE resources or specific features like lecture recordings or multiple-choice quizzes. To our knowledge, the current paper is the first to analyse how the use of all VLE features affects performance on a module as part of the full mix of learning resources. In the analysis, we address the following research question:

3) Which learning resources are most crucial to student success on a module?

3. Empirical Analysis

3.1 Context

We use secondary data for undergraduate students on a 2nd year module delivered at a UK University, Nottingham Trent University. It is a core module in the Economics of

Banking delivered to 2nd year full-time students on an Economics with International Finance and Banking degree. Different learning resources were expected to be used in a complementary way to develop deeper knowledge and understanding.

In the 2019/2020 academic year, delivery was largely through live face-to-face lectures and seminars, with a range of additional VLE features. There was a significant teacher presence in guiding learning - tutors provided guidance in the face-to-face classes regarding the sequence of learning incorporating the VLE features. The start of the learning process for a topic involved attending a lecture which introduced a topic and developed threshold knowledge and understanding. Polling software was used in lectures to review understanding. The lectures were recorded and could be viewed on-demand via the VLE. Copies of the lecture slides were provided on the VLE in advance of the lecture to help engagement during the session. After that, students were expected to attend a seminar to develop knowledge and understanding through a critical application of theory. Open-ended questions were provided on the VLE to help frame independent study to deepen their learning. Answers to these were published on the VLE after two weeks.

In 2020/2021, the University migrated to an online delivery model. While the intended workload was equivalent to 2019/2020, the way in which students engaged with the learning process changed. With no face-to-face lecture, the 'teacher presence' guiding learning at the start of each topic was provided using a study guide published on the VLE. The study guide explained the different learning resources and the sequence in which they were to be used to deepen knowledge and understanding. The learning process started with lecture recordings (approximately 6*10 minutes) which were available on-demand. Slides were provided to complement the recordings. The interactive questions previously used in lectures were converted to online multiple-choice quizzes to be completed after watching the recordings to review knowledge and understanding. Students then attended a live, online seminar to develop knowledge and understanding through a critical application of theory. As in 2019/2020, further open-ended questions were provided on the VLE to encourage deeper learning. Answers to these questions were published on the VLE after two weeks. In this academic year, online discussion forums were also included to help facilitate interaction between tutors and students and between students. Therefore, some of the learning resources previously provided in a live, face-to-face setting were changed to

an on-demand setting through the VLE. Others done in a live, face-to-face setting were changed to a live, online setting. Table 1 illustrates the learning resources in the different academic years.

Table 1: Dimensions and Sequence of Learning Resources and related Assessment in each year of delivery

Academic Year 2019/2020	Academic Year 2020/2021
2-hour live face-to-face lecture including interactive quizzes On-demand Lecture recording – 1*100 minute recording per topic (VLE) Lecture Slides (VLE) 2-hour live face-to-face seminar On-demand activities with guidance (VLE)	Study Guide (VLE) On-demand Lecture recordings – 6*10 minute recordings per topic (VLE) Lecture Slides (VLE) On-demand interactive quiz (VLE) 2-hour live online seminar On-demand activities with guidance (VLE) Discussion forum 1-hour live online Q&A
Assessment: 100% online open-book examination	Assessment: 30% Recorded group presentation 70% Online open-book examination

In 2019/2020, Economics of International Banking was assessed with an open-book examination. Following the migration to online delivery, some changes to assessment were made. The module incorporated a recorded group presentation weighted at 30% of the module grade. The open-book examination was weighted at 70%.

3.2 Data

At Nottingham Trent University, data on attendance at classes and the use of VLE features are collected. These data are used to monitor the engagement of students. Reports are available for lecturers to monitor students' access of features on modules to monitor their engagement. We used these reports to measure use of module-level

learning resources. We source data on academic performance and independent control variables from the University's student records[2].

Students' preferences for different learning activities are measured in the following ways. For both cohorts, the preference for on-demand lecture recordings is measured by the average (mean) percentage of on-demand lecture recordings viewed by a student. Their preference for using copies of lecture slides as a learning resource is measured as the percentage of the total number of such pdf files available which are accessed by a student. We measure the preference for seminars as the percentage of total seminars attended either face-to-face (2019/2020) or online (2020/2021). Preference for additional open-ended online questions is determined by the average time spent on the VLE pages measured as a percentage of the average anticipated completion time (typically one hour). The greater the percentage, the greater the preference for this learning resource. For the 2019/2020 cohort we also measure attendance rates for live lectures to assess student preference for that learning resource. For the 2020/2021 cohort, additional VLE features were introduced. We determine a preference for online self-study multiple-choice quizzes as the percentage of the total number available which are completed by a student. Discussion forums were also introduced in 2020/2021. However, these were barely used so are excluded from the analysis that follows.

In the regression analysis that examines which learning resources are crucial to student success on a module, the dependent variable is measured as the overall mark attained by a student on the module using a percentage scale. When analysing the relationship between use of learning resources and academic performance, one must be careful to control for other factors which can influence attainment. These have been noted in research analysing attainment in UK Higher Education (for example see Dascalu et al., 2021; Jones et al., 2017). We use students' Grade Point Assessment (GPA) of entry qualifications as a measure of prior ability. Further, we employ binary variables to reflect a students' gender, whether they were mature at the time of enrolment; whether they are resident outside the UK and whether they are part of disadvantaged groups under-represented in higher education identified as

[2] We gained ethical approval from Nottingham Trent University for the use of this data.

part of widening participation policy (Gorard et al., (2019)[3]. Table 2 provides the names and definitions of the dependent and independent variables and their expected signs in the regression analysis.

[3] The main indicators include Participation of Local Area (POLAR); Indices of Multiple Deprivation (IMD); ACORN demographics and household income data.

Table 2: Names and Definitions of Variables and their expected signs in regression analysis

Name	Definition	Expected sign
Mark	Percentage mark attained by a student	
Lecture Attendance	Percentage of 'live' lectures attended by a student (2019/2020 only)	+
Lecture Recordings	Average percentage of recorded lectures watched by a student	+
Slides	Percentage of total lecture slide packs accessed by a student	+
Online Quizzes	Percentage of total quizzes available completed by a student (2020/2021 only)	+
Seminar Attendance	Percentage of 'live' seminars attended by a student	+
Online Questions	Average time spent on online open-ended questions as a % of expected completion time	+
GPA	Entry qualifications recorded as a Grade Point Average (GPA)	+
Gender	Binary variable with a value of 1 if a student is female; otherwise 0.	+
Age	Binary variable with a value of 1 if a student was more than 20 years of age at time of enrolment; otherwise 0.	+
Residency	Binary variable with a value of 1 if a student is not a UK resident; otherwise 0.	-
Widening Participation	Binary variable with a value of 1 if a student was defined as a part of disadvantaged group under-represented in higher education as part of widening participation policy; otherwise 0.	-

3.3 Methods of Analysis

3.3.1 Engagement Analysis

To address the first two research questions, we analyse students' patterns of use of different learning resources in both the 2019/2020 and 2020/2021 academic years. In both years, the learning resources were expected to be used in a sequential manner to develop deeper knowledge and understanding of each topic. Different patterns in usage will indicate the extent of the limit which students place on each learning resource and their preference for different resources in learning. This will help identify if students' usage of VLE resources is consistent with the existing literature.

To assess the extent of use of each learning resource, we compare actual average use against the anticipated cognitive maximum. This cognitive maximum is represented as complete use - 100% use of resource. Less than complete use of learning resources would indicate students placing a limit on their cognitive load.

We analyse the patterns of use to analyse the factors which influence students' management of cognitive load proposed in the literature. Firstly, we assess sequential bias by analysing whether the sequence in which students are expected to use resources influences the pattern of actual use observed. If sequential bias is present, the average use of resources cued early in the learning sequence for each topic would be used more than those cued later.

Secondly, we assess a potential bias for familiar learning resources to limit cognitive load by analysing how use of resources changed from the face-to-face learning environment to the online learning environment. We analyse how the use of resources available in both 2019/2020 and 2020/2021 changed following the migration to online learning. We also analyse the use of new VLE features offered in 2020/2021 to assess the extent to which these were incorporated into learning. If these were not used extensively, it would indicate a preference for familiar learning activities.

To assess the extent to which students are instrumental in learning, we assess whether there is a preference for passive learning resources which indicates a focus on surface learning. This would be primarily lecture attendance in 2019/2020 and lecture recordings and lecture slides in 2020/2021. Active learning resources such as

the multiple-choice quizzes and online open-ended questions which are expected to facilitate deeper learning will have less value attached to them and exhibit lower use.

3.3.2 Regression Analysis

To address the third research question, we employ cross-sectional regressions to analyse students' attainment in relation to engagement with different learning activities in each learning environment (face-to-face and online). We run separate models for each learning environment to analyse the relationship between marks attained and the use of the different learning activities available in each year. Model 1 relates the mark achieved by students to learning activities used in 2019/2020 and incorporates the control variables explained in Section 3.2 above. This is shown in equation 1.

$$\text{Mark} = \beta 0 + \beta 1\text{Lecture Attendance} + \beta 2\text{Lecture Recordings} + \beta 3\text{Slides} + \beta 4\text{Seminar Attendance} + \beta 5\text{Online Questions} + \beta 6\text{GPA} + \beta 7\text{Gender} + \beta 8\text{Age} + \beta 9\text{Residency} + \beta 10\text{Widening Participation} + \varepsilon \quad (1)$$

Model 2 relates the mark achieved by students to learning activities used in 2020/2021 and again incorporates the control variables explained in Section 3.2 above. This is shown in equation 2.

$$\text{Mark} = \beta 0 + \beta 1\text{Lecture Recordings} + \beta 2\text{Slides} + \beta 3\text{Online Quizzes} + \beta 4\text{Seminar Attendance} + \beta 5\text{Online Questions} + \beta 6\text{GPA} + \beta 7\text{Gender} + \beta 8\text{Age} + \beta 9\text{Residency} + \beta 10\text{Widening Participation} + \varepsilon \quad (2)$$

4. Results

4.1 Engagement with Learning Resources

Table 3 illustrates descriptive statistics for student engagement with sequenced learning activities during the 2019/2020 delivery of the module. Table 4 illustrates some descriptive statistics for student engagement with learning activities during the 2020/2021 delivery. The tables present the learning activities in the sequence they were intended to be completed for each topic in order to develop and deepen knowledge and understanding.

Table 3: 2019/2020 Learning Resources Descriptive Statistics

	% of Lectures attended	Average % of on-demand lectures watched	% of Lecture slide files accessed	% of Seminars attended	Average time spent on open-ended questions as a % of expected completion time
Mean	32.69	26.41	43.19	53.14	4.89
Median	33.00	19.00	44.44	50.00	0.44
Max	100.00	88.89	88.89	100.00	100.00
Min	0.00	0.00	0.00	0.00	0.00
% student use below 33.33%	52.83	67.92	32.08	24.53	98.11
% student use above 66.66%	24.53	13.21	30.19	45.28	1.89

Number of students = 53

In 2019/2020, most of the available learning resources exhibited the full range of engagement from zero to near or full use. On average, synchronous resources were more popular than asynchronous ones. The synchronous face-to-face seminars were the most popular learning activities in this learning environment. The median student attended half the seminars and 45% of students attended more than two-thirds. Of the asynchronous materials available, average use of lecture slides was highest. Indeed, average use of this resource was higher compared to the live lecture. Average use of the online open-ended questions was much lower. While the average time working on these was 4.89% of the expected completion time of 1 hour, the median was less than 1%. Indeed, approximately 98% of the students spent less than a third of the expected cognitive maximum time on them.

Table 4: 2020/2021 Learning Resources Descriptive Statistics

	Average % of on-demand lectures watched	% of Lecture slide files accessed	% of Online on-demand quizzes completed	% of Seminars attended	Average time spent on open-ended questions online as a % of expected completion time
Mean	47.7	43.3	23.0	46.6	3.10
Median	49.1	38.5	22.2	45.5	0.21
Max	96.0	100.0	88.9	100.0	46.67
Min	0.0	0.0	0.0	0.0	0.0
% student use below 33.33%	39.1	46.4	65.2	36.2	98.6
% student use above 66.66%	36.2	23.2	2.9	30.4	0.0

Number of students = 69

In 2020/2021, the overall pattern of use was not very different from 2019/2020. Most of the learning resources again exhibited the full range of usage from zero to near or full average use. The exception was use of online open-ended questions which had a maximum average use of 46.67%. In this online learning environment, recorded lectures exhibited the highest average use, which was significantly higher than 2019/2020. This was likely to be due to the lack of a live alternative. Average seminar attendance and use of lecture slides were similar in the two learning environments. There was no significant change in the use of the active, online open questions in 2020/2021. Meanwhile, the new asynchronous on-demand quizzes which were intended to be completed after watching the lecture recording to review knowledge and understanding while attracting some use, were significantly less popular that

lecture recordings, slides and seminars. The average completion rate was 23%, but only a minority used these extensively – 65% of students completed less than 3 of the 9 available. As stated above, discussion forums were barely used.

Across both cohorts, the results provide support for the cognitive load theory of multimedia. Average use of the learning resources was significantly below the maximum anticipated cognitive maximum. While some students on average demonstrate full or close to full usage for some learning resources, none maintained that level across all learning resources. This indicates that even the most engaged students were selective in their use of learning resources. This suggests there is a limit to the amount which even highly engaged students can consistently engage with. Tutors should appreciate this limit to cognitive load when determining their expectations about what constitutes high engagement.

The tables above present the learning resources in the sequence they were intended to be used. Students were encouraged to use the learning resources in a particular sequence to deepen knowledge and understanding. However, the overall pattern of use is not consistent with a bias towards resources cued early in the sequence to manage cognitive load. For instance, in 2020/2021, the 'live' online seminars were more popular than the multiple-choice quizzes which were expected to be completed earlier in the learning sequence. However, when focusing on the use of asynchronous VLE resources in the learning process (lecture recordings, lecture slides, online quizzes and online open-ended questions), there is evidence of sequential bias. On average, asynchronous resources which were expected to be used earlier in the sequence of learning were used more than resources which were expected to be used later. This trend is more evident in 2020/2021 when more engagement was expected via these asynchronous resources.

One interpretation of this is that faced with the novel, online learning environment in 2020/2021, students reverted to the familiar, preferring learning resources they may have used in previous study. Asynchronous active learning resources were not used significantly more by students in the online learning environment, suggesting that students may not have found them valuable as a complement to the familiar.

Another interpretation for the pattern of use observed is instrumentalism. Faced with a plethora of synchronous and asynchronous learning resources in both learning

environments, students identified the subset of learning resources which were most valuable to achieving the desired outcome in assessment. They did not want to develop a deep understanding across all topics in a module, only a subset. This is evident through the greater use of VLE features which develop a surface understanding of topics (lecture recordings) and lower use of activities which develop deeper understanding (online open-ended questions). Indeed, approximately 98% spent less than one third of the expected time working on the latter resources, suggesting they did not feel they need that depth of understanding to achieve their desired outcome in the assessment. Even for those students who exhibited some use of the online open-ended questions, our findings suggest that students use these resources in selected topics to develop deeper understanding. These may be topics they selected to answer in the assessment to try to gain a higher mark.

4.2 Regression Results

The descriptive statistics for the dependent variable and control variables are presented in Appendix 1. Table 5 shows the regression results. Model 1 shows the results of the regression for 2019/2020. Due to gaps in GPA data, the number of observations used in the regression is 47. Model 2 shows the results for 2020/2021. Again, due to gaps in GPA data, the number of observations used in the regression is reduced to 67. An analysis of the residuals for both models indicated heteroscedasticity. Consequently, we report White robust standard errors below.

Table 5: Regression Results

Independent variables	Model 1 (2019/2020)	Model 2 (2020/2021)
Constant	34.020***	11.638
	(4.283)	(9.381)
Lecture Attendance	-0.053	N.A.
	(0.041)	
Lecture Recordings	-0.042	0.102*
	(0.038)	(0.06)
Slides	0.051	0.153***
	(0.038)	(0.047)
Online Quizzes	N.A.	-0.103
		(0.098)
Seminar Attendance	-0.033	-0.008
	(0.043)	(0.059)
Online Questions	0.046	0.297*
	(0.049)	(0.176)
GPA	3.531***	4.274***
	(0.518)	(0.965)
Gender	5.264**	-1.914
	(2.306)	(4.516)
Age	-0.336	-23.093***
	(2.863)	(7.659)
Residency	-2.778	2.404
	(2.634)	(6.135)
Widening Participation	-2.313	2.784
	(2.542)	(6.441)
R^2	0.705	0.647
N	47	67

* indicates significance at 0.1 level
**indicates significance at 0.05 level
***indicates significance at 0.01 level
N.A. indicates not applicable
Dependent variable is module final mark
White robust standard errors reported in parentheses

In the face-to-face learning environment in 2019/2020, none of the complementary learning activities were significant in determining the mark attained, ceteris paribus. In contrast, in the model for the online learning environment in 2020/2021, several VLE features had a significant positive influence on mark, holding all else constant. An increase in the average percentage of lecture recordings watched was associated with

a higher mark. This is consistent with Flores and Savage (2007). We add to the literature by finding that an increase in the access rate of lecture slides was associated with a higher mark. Further, greater average percentage of expected time spent on online open-ended questions was associated with a higher mark. This suggests that in the online learning environment use of these complementary resources were much more significant to success than in the face-to-face learning environment. Seminar attendance was not significant in either environment suggesting that this measure may not represent a proper reflection of learning using that resource. Mere attendance may not reflect proper engagement with that resource. Of the new asynchronous resources introduced for 2020/2021, results indicate that the completion of online quizzes was not significant in determining the mark attained on the module. The weak learning benefits associated with this resource is consistent with previous work (see Moffat and Robinson; 2015). Results from this analysis suggest also that the less significant 'teacher-presence' in the online learning environment meant that the use of a subset of complementary asynchronous learning resources was more crucial for learning and attainment. The subset of valuable VLE features included those which developed threshold knowledge and understanding. Importantly, results show that the use of the complementary online open-ended questions which facilitated deeper knowledge and understanding were significant in raising academic attainment on the module during online delivery. This suggests that the students who made selective use of this resource benefitted significantly from incorporating it their learning.

Of the control variables, prior ability measured by GPA was a significant determinant of attainment in both learning environments, ceteris paribus. In 2019/2020, the coefficient on gender was significantly different from zero, indicating that females were more likely to achieve higher marks. This result is particularly interesting as Montolio and Taberner (2021) conclude that female students perform worse in high stakes assessments but the results in Table 5 contradict their result, with female students doing significantly better, ceteris paribus, in the earlier 2019/2020 academic year when there was a single 100% weighted final examination. Meanwhile, in 2020/2021, mature students were more likely to have significantly lower marks, holding all else constant.

5. Conclusions

The more widespread use of online learning tools by universities due to the Covid-19 pandemic has focused attention on which features of Virtual Learning Environments (VLEs) students value in learning. Previous work has either analysed stated preferences of students for VLE resources through surveys or revealed preference of specific features like lecture recordings. Adopting a revealed preference framework, this paper adds to the literature by analysing the use of VLE features as a complement to other learning resources. We analyse the use of learning resources in a pre-pandemic face-to-face learning environment and an online learning environment in the context of the cognitive load theory of multimedia. We also evaluate which learning resources had a significant impact on academic attainment in both learning environments.

We used data on student engagement and attainment in a 2nd year undergraduate module in the Economics of International Banking delivered at a UK University. Data from both 2019/2020 and 2020/2021 are utilised in the analysis. Our analysis indicates that of the learning resources offered in both environments, only average access rates for lecture recordings was significantly higher when delivery was online. In both environments, evidence supports the cognitive theory of multimedia. Students' selective engagement with learning resources indicated they were managing their cognitive load. On average, students demonstrated a preference for familiar learning activities such as lectures and seminars. Instrumentalism was also evident in patterns of use. Passive learning resources like lecture recordings were used more than active ones such as open-ended questions, indicating a tendency for many students to focus on surface learning. However, while the regression results show that in the online learning environment passive resources like lecture recordings and slides had a significantly positive impact on the mark achieved, so did the use of online open-ended questions. This suggests that selective use of this complementary resource was important to achieving deeper learning and higher marks.

Our work reflects the experience on one 2nd year core economics of banking module across two cycles of delivery. Since models of online delivery across universities, the external validity of our results is limited. Therefore, analysis of similar modules at different types of UK universities would enable comparisons of engagement in

economics education. In addition, further work could investigate the pattern of use of VLE features in modules at different stages, particularly final year where engagement may be expected to be higher due to its importance in determining degree classifications. Work in the future could investigate the changing use of VLE resources over longer time frames. In addition, we measured engagement with the module's learning resources in an approximate way. A more nuanced analysis of the use of VLE features as part of broader learning could draw out when resources are used and how frequently students use resources. Further work could also draw out the qualitative aspect of the learning achieved in using resources. Finally, we cannot measure the extent of independent self-guided study completed by students and its impact on attainment.

Despite the limitations, since some of the core features of VLEs are common – for instance lecture recordings, online quizzes and discussion forums - these need to be incorporated effectively into the mix of complementary learning resources. Our results provide guidance on how students use complementary learning resources which will be of value to lecturers designing delivery models incorporating VLE features. Students revealed a preference for a subset of learning resources which supports the cognitive load theory of multimedia. Consequently, lecturers' expectations about how much overall use they should expect needs to be tempered by this reality. While the overall use of active resources promoting deeper knowledge and understanding such as open-ended questions were lower than that of passive resources such as lecture recordings, our findings indicated that providing these resources was not wasteful. More engaged students were selective about the topics where deeper understanding was required. Hence, they were selective in their use of the online open-ended questions as a complement to others in the online learning environment to improve attainment. Consequently, resources which promote deeper learning are perceived as valuable but tutors should focus on guiding more students to use them effectively.

Acknowledgements

We would like to thank participants at the 2021 Developments in Economics Education conference for helpful comments. We are also grateful to an editor and reviewers from this journal for their insightful suggestions that helped us improve the paper.

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Appendix 1

Descriptive Statistics for the two cohorts

Descriptive Statistics	**2019/2020**	**2020/2021**
Number of Students	53	69
Mean Mark	64.7	59.7
Mean GPA[1]	9.7	8.9
Percentage with Male Gender	79.3	85.5
Percentage who entered as mature students	3.8	1.5
Percentage with UK Residency	83	82.6
Percentage from a Widening Participation (WP) background	18.9	15.9

Note only 47 students in 2019/2020 and 67 students in 2020/2021 had GPA data