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Individual Differences in Students' Use of Optional Learning Resources

Matthew Inglis, Aruna Palipana, Sven Trenholm, Joe Ward

Loughborough University

Address correspondence to:

Matthew Inglis, Mathematics Education Centre, Loughborough University, Loughborough,

Leicestershire. LE11 3TU.

Email: m.j.inglis@lboro.ac.uk

Abstract

We investigated ways in which undergraduates use optional learning resources in a typical blended learning environment. Specifically, we recorded how often students attended live face-to-face lectures, accessed online recorded lectures and visited a mathematics learning support centre during a multivariate calculus course. Four distinct study strategies emerged, but surprisingly none involved making heavy use of more than one resource. In contrast with some earlier research, the general strategy a student adopted was related to their academic achievement, both in the multivariate calculus course, and in their degree programme more widely. Those students who often accessed online lectures had lower attainment than those who often attended live lectures or the support centre. We discuss the implications of these findings and suggest that "blended teaching environments" may be a more accurate description for what have previously been called "blended learning environments".

Individual Differences in Students' Use of Optional Learning Resources

Introduction

In recent years it has become commonplace for universities to offer students considerable choice in how they study. Whereas in the past students attended live classes and had access to a library, it is now common for them to be provided with access to online sets of lecture notes, drop-in support services, online forums and so on, as well as the more traditional live classes and libraries. The advocates of such so-called "blended learning", "HyFlex" or "hybrid" environments emphasise learner choice and flexibility (Beatty, 2007; Lewis, 2002). The idea is straightforward: provide students with an array of resources, and allow them to choose what they deem to be the most effective means of achieving the module learning outcomes. While such an approach is recognised as beneficial for students studying at a distance, the benefits of flexible learning for on-site students are unclear (Gosper, Green, McNeill, Phillips, Preston & Woo, 2008).

The current literature on blended learning environments provides insight into how various individual options (e.g., live or online lectures, academic support, web-based assessment) tend to be used (e.g., their effects on attendance and study strategies), as well as certain findings about the efficacy of each option (e.g., final exam performance, overall module grade). What remains poorly understood is the overall pattern of study choices made when students are presented with many options. That is, are there individual differences in the range of study resources adopted by students? Do these individual differences fall into distinct study strategies? If so, how do these different strategies relate to academic success? These questions are the focus of the present study.

In this paper we consider three specific learning resources that are commonly provided to undergraduate students studying mathematics or subjects with a large mathematical component: live lectures (LLs), online lectures (OLs) and mathematics learning support

centres (MLSCs). We first briefly review what is known about each of these learning resources.

First, we discuss the centrepiece of tertiary instruction: the traditional or "face-to-face" lecture. In keeping with constructivist ideas, some have declared that the traditional lecture, as a transmissionist form of instruction, is dead or dying (Folley, 2010). Others, in part arguing for the disciplinary distinctiveness of disciplines such as mathematics, write in support of the enduring value of LLs (Pritchard, 2010). While the fate of lecturing may remain unclear, some recognised benefits include affective (e.g., a sense of belonging, increased motivation, peer interaction) and cognitive attributes (e.g., an ability to ask questions of peers and the lecturer, live modelling of concepts or processes; Cretchley, 2005; Pritchard, 2010). In terms of efficacy, the situation is complex and likely to be dependent on variables such as the lecture material, the lecturer's approach to lecturing, the student's approach to studying, the time of day, and so on (e.g., Pascarella & Terenzini, 1991).

While still in their infancy, OLs (variously referred to as web-based, virtual, captured, video, digital, webcasts or e-lectures[1]) present a second option to LL attendance. Technological advances in network infrastructure and software developments present an opportunity for institutions to provide OLs as either a support (before or after class) or even as a full replacement for "going to class". Research on pedagogical effectiveness in this area, as in so many other instructional technology areas, continues to lag behind innovations.

Most research concerning OLs is action-based, and usually involves either self-report survey questionnaires, computer log files and/or interviews. Areas of general interest include the effect that providing OLs in addition to LLs has on LL attendance and on overall learning outcomes. While the vast majority of studies show that the effect on LL attendance is insignificant (Craig, Wozniak, Hyde, & Burn, 2009; Davis, Connolly, & Linfield, 2010; Hubbard, 2007; Larkin, 2010; Toppin, 2010), the picture is less clear regarding the effect on

learning outcomes. Most studies indicate either no negative effects (Bassili, 2008; Signor, 2003; Von Konsky, Ivins, & Gribble, 2009) or some positive effects (Edirisingha & Fothergill, 2010; Grabe & Christopherson, 2008; Wieling & Hofman, 2009) with few concluding there was a negative impact on learning (Ross & Bell, 2007). A few cautions are worth noting. First, few studies in this field are genuinely experimental (i.e. do not randomly assign participants to conditions), and so it is difficult to legitimately draw causal conclusions about the relationship between OLs and learning outcomes (Bassili & Joordens, 2008; Grabe & Christopherson, 2008). Second, even if academic outcomes may be better when students watch OLs as well as attend LLs, some question whether the quality of the learning derived from OLs reflects more of a surface or rote memorisation (Le, Joordens, Chrysostomou & Grinnel, 2010; Joordens, Le, Grinnel, & Chrysostomou, 2009), that may be more suited to introductory modules characterized by "knowledge acquisition" learning (Demetriadis & Pombartsis, 2007, p.156). Lastly, it is important not to oversimplify such findings given the likelihood that discipline, institution, student demographics, quality of presentation, and so on, are likely to play a significant role in any results – such variations represent important avenues for future research efforts.

What appears to be one of the most consistent uncontested findings is that OLs serve to increase student satisfaction (Davis, 2010; Folley, 2010; Gosper et al., 2008; Le et al., 2010). Bassili and Joordens (2008) went as far as suggesting that any effect on learning appeared "to be mediated by increased enjoyment of the learning environment" and is not directly dependent on the OL provision itself. While students appreciate the flexibility, some suggest that there may be too much (Bell, Cockburn, McKenzie, & Vargo, 2001; Demetriadis & Pombartsis, 2007) and that students need instruction on how best to use OL resources (Joordens et al., 2009; Le et al. 2010).

Of the three learning resources discussed in this paper, perhaps the least familiar is the mathematics learning support centre (MLSC). Such centres, commonly set up in response to the perceived decline in the mathematical skills displayed by incoming undergraduate students, offer help to undergraduate students on a drop-in basis outside of module-specific tutorials or problem classes. Typically staffed by mathematics faculty or dedicated student support officers, MLSCs are becoming more common across at least the UK higher education sector. For example, in 2001 it was found that 48% of UK universities offered some level of mathematics support provision; the figure in 2004 was 62% (Perkin & Croft, 2004), and is known to have increased since that point. Similar centres operate in non-UK contexts (Mac an Bhaird, Morgan, & O'Shea, 2009a; MacGillivray, 2009). Support Centres differ from 'office hours' provision in several important ways. First, they typically are located in dedicated resource-rich spaces which can be used both as a way of accessing drop-in support, and as a location for private study. Second, students can work together in small groups and ask for support collaboratively. Third, the student-centred nature of MLSCs appears to result in undergraduates taking greater ownership of the spaces, and consequently being more willing to access support than they might otherwise be (Solomon, Croft & Lawson, 2010).

Creating and operating MLSCs is resource intensive both in terms of staff and estates costs, so it is unsurprising that their efficacy has been studied. MLSC provision has been shown to (i) improve attendees' mathematical confidence (Mac an Bhaird, Morgan, & O'Shea, 2009b), (ii) increase attendees' progression rates (Pell & Croft, 2008; Mac an Bhaird et al., 2009a; MacGillivray, 2009), (ii) result in positive student feedback scores and institutional audit reports (e.g. QAA, 2008).

Given the emphasis on the provision of multiple learning resources in "blended" or "HyFlex" learning environments, it is perhaps surprising that the majority of studies discussed above have studied how students engage with a single resource. There are,

however, some exceptions to this rule. Bassili (2006) asked students to self-report their LL

attendance and use of OLs in an introductory psychology class. He found no relationship

between reported study strategy and examination performance, but did find an association

between students' Big Five personality profiles and their strategy choices: students with high

neuroticism profiles claimed to attend LLs more often than those with low profiles. If a

student's personality type influences their reported learning strategies in blended learning

environments, it seems plausible to suppose that there are substantial individual differences in

how students negotiate such environments.

Our aim in this paper is to use behavioural (rather than self-report) data to investigate

whether there are individual differences in students' use of optional learning resources in the

context of a university mathematics course which included LLs, OLs and access to an MLSC.

Specifically, we asked: How do students coordinate the multiple learning resources that they

are provided with? Are there individual differences in the learning strategies that they adopt?

Do these individual differences represent a small number of distinct study strategies? And, if

so, are such strategy differences related to differences in academic outcomes? To address

these issues we recorded students' use of LLs, OLs, and the MLSC during a course on

multivariate calculus.

Setting of the Study

The study took place at Loughborough University, a research-intensive university in the

midlands of England. Data were collected from three modules, chosen because of the similar

course content and the willingness of the lecturer to participate. Each module was taught by

the same lecturer, and covered multivariate calculus. Two of the modules were taken by

undergraduates studying engineering (mechanical engineering and aeronautical/automotive

engineering), the third was for those studying single or joint honours mathematics. Each

module lasted for one semester of fifteen weeks, twelve of which had lectures, with the remaining three weeks consisting of revision and examinations.

At the start of each module the lecturer informed students that he had produced web-based lectures which had been uploaded to the institution's Virtual Learning Environment (VLE). He encouraged students to view these OLs as preparation for each LL (there was a one-to-one pairing between the LLs and the OLs). The OLs consisted of staged audio recordings of the lecturer explaining the course content synchronised with relevant visual displays (of formulae, diagrams etc). Lectures were produced by the lecturer at his office computer using PowerPoint's narration functionality, and were uploaded to the VLE well before the corresponding LL. Students could stop, pause and replay the audio which accompanied each visual display as many times as they wanted.

The LLs consisted of the lecturer covering the same material as was available online, using the same examples. Along with the inevitably greater interaction between lecturer and student due to the live setting, two major differences from the OLs were: first, that the lecturer made use of an Electronic Voting System (EVS) to increase student participation, and second, he actively encouraged students to ask questions during the sessions. Attendance at the LLs was strongly encouraged, but was not a requirement.

At the beginning of the module the lecturer also highlighted the availability of the MLSC, explained how it operated, and encouraged students to make use of it. Those students registered on degrees in the mathematics department would also have been encouraged to use the centre by their personal tutors, and by general advertising around the department. Additionally, at the start of their degree course, each student had taken a diagnostic mathematics test which covered material taught during their final years at school (the tests taken by the mathematics undergraduates were slightly different to those taken by the engineering students). Students who performed poorly on the tests were encouraged by their

personal tutors to work through revision materials and visit the MLSC. The MLSC was open for independent study everyday during the semester from 10am to 5pm. A drop-in tutor was on duty to answer questions and provide individual support every day from 11am to 1pm and 2pm to 4pm.

All three modules were assessed via a final examination, and various coursework assignments.

Method

Along with diagnostic test scores and final module grades, we recorded the use that each student made of three specific optional study resources: the LLs, the OLs and the MLSC.

Students were required to register their presence at each LL by swiping their university library card on entry. This was enforced by the lecturer and a research assistant who attended the start of each session. Students who did not bring their cards to the lecture were required to write down their ID number. Although there is some evidence in the literature that recording student presence at lectures boosts attendance (Shimoff & Catania, 2001), we do not believe that this was a major factor in this case. At 56%, the overall mean attendance was low, and the lecturer reported that this figure was in line with his impression of the attendance in previous years that he had taught the modules.

OL use was recorded automatically by the VLE. Students were required to login with their university ID and password to access the VLE, and the number of times each OL was accessed was recorded.

Students were required to swipe their university card every time they entered the MLSC. This was enforced by a receptionist stationed near the entrance of the centre.

At the end of the data collection period students were informed of the purpose of the study and asked to give consent to their data being used. The data gathered from the eight students who withheld consent were destroyed prior to analysis. A total of 534 students agreed to

participate in the study, comprising 237 students on the mathematics module and 163 and 134 students on the two engineering modules.

There are several important limitations to the sources of data that we used. Specifically, although we can say with accuracy how many times each student engaged with each resource, we do not have data that speaks to the quality of their engagement. For example, we do not know whether students gave their full attention in LLs, we do not know how long each student spent watching each OL, and we do not know how long each student spent working in the MLSC, or how much time they spent working with the drop-in tutor (if at all) during their visit. A further limitation relates to the MLSC data. The MLSC offers mathematics support related to any mathematics module, consequently we cannot be sure that a student registered on one of the modules included in the study was visiting the centre about the content of this module. This is a particular issue for the mathematics undergraduates in the study, who were simultaneously studying several other mathematics modules (between two and five, depending on their degree programme). The engineering undergraduates were not studying any other mathematics modules at the time of the study.

One final caveat relates to the extent to which students engaged in learning activities using resources that we did not monitor. For example, most teaching professionals regard tackling problem sheets as an important component of learning university-level mathematics (e.g. Pritchard, 2010). Since we have no measures of the extent to which students engaged with the problem sheets associated with the modules that we investigated, we cannot claim to have collected data on every aspect of the students' learning activity. Nevertheless, formal contact hours do form a substantial component of student learning in undergraduate mathematics courses: the mathematics undergraduates in this study had 19 timetabled contact hours per week, and the engineering undergraduates had between 26 and 32 (depending on their lab work schedule).

In sum, although there are important caveats associated with these data, we believe that they do give a useful indication of students' patterns of engagement with optional learning resources.

Results and Discussion

The Four Clusters

Students' access/attendance figures for the three learning resources were standardised (i.e. converted into z-scores) and entered into a hierarchical cluster analysis, using Ward's method with a Euclidean squared distance metric. A four-cluster solution was extracted, which accounted for 59% of the variance in usage measures. Cluster stability was examined via a split-half method, with the four-cluster solution found to have substantially higher stability than either the three- or five-cluster solutions. This was assessed by computing Rand's (1971) index, the probability of agreement between the split-half clustering and the clustering on the entire dataset. The three-, four- and five-cluster solutions had Rand Indices of 78.3%, 93.3% and 86.7% respectively.

The behavioural data for the four clusters is shown in Figure 1. Cluster 1 (N=70) had higher than average (an average figure would be represented by a z-score of 0) access figures for the OLs, but below average attendance at the LLs and the MLSC. Cluster 2 (N=214) had higher than average attendance at the LLs, but below average access of the OLs and attendance at the MLSC. Cluster 3 (N=65) had higher than average attendance at the MLSC, average attendance at the LLs, and below average access of the OLs. Cluster 4 (N=185) had below average access/attendance at all the learning resources we considered. The mean unstandardised figures for each cluster are given in Table 1.

Insert Figure 1 about here

Insert Table 1 about here

We had expected that there would be a cluster of students who would often attend LLs and access OLs (as recommended by the lecturer), or that some students would primarily learn by accessing OLs coupled with visits to the MLSC to receive specific support on difficult topics. Neither of these expectations were confirmed; students appeared to make above average use of at most one learning resource. Indeed, there was no cluster that could be described as being engaged in genuinely "blended learning": students typically made heavy use of only one learning resource, or none at all.

We were also surprised by the large number of students who appeared to access/attend with below average frequency all three learning resources considered in this paper (Cluster 4 had 185 members, representing 35% of the sample). Although it is possible that these students were using other learning resources that we did not consider (textbooks from the library, online forums, independent study groups, etc), based on the relative examination performance of the clusters (discussed later) we do not believe that this was the case to any great extent.

The make-up of the four clusters was analysed in terms of subject-specialism and gender. There was a significant relationship between students' subject specialism (engineering or mathematics), and their cluster membership, $\chi^2(3)=89.2$, $p<.001$. This relationship appeared to be driven by two factors. Firstly, a majority (80%) of Cluster 3 (the heavy MLSC attendees) were mathematics undergraduates. This is unsurprising, as the MLSC is a service administered by the mathematics department, and so we would expect students based in the department to (a) be more aware of the service the centre offers, and (b) have greater need of

it. A more surprising factor was that a large majority (96%) of Cluster 1 (the heavy OL users) were engineering undergraduates. As there was an equal opportunity for students to access the OLs in all the courses, and as all students were given the same encouragement to do so, we do not believe there were any technical issues that can account for this finding. It may simply be that students' willingness to use e-learning resources is related to their discipline of study (perhaps because of different timetable loads), a suggestion consistent with earlier research on the relationship between learning approaches and disciplines of study (e.g., Smith & Miller, 2005; White & Liccardi, 2006).

There was a borderline significant relationship between students' gender and their cluster membership, $\chi^2(3)=7.46$, $p=.059$. There were proportionately fewer women in Clusters 1 and 4 than men (9% versus 14% and 28% versus 36% respectively) and proportionately more women in Clusters 2 and 3 than men (46% versus 38% and 17% versus 11% respectively). Looking at the gender-differences in mean usage figures across the sample showed that (i) significantly more men accessed OLs than women, Mann Whitney $U=19675$, $p=.001$, (ii) there was a borderline significant difference between LL attendance, with women attending more often than men, $t(208.3)=1.86$, $p=.064^2$, and (iii) there was no significant difference between the two genders' use of the MLSC, Mann Whitney $U=23775$, $p=.392$. Earlier researchers have suggested that MLSCs are particularly valued by, and valuable for, female students (Solomon et al., 2010); if this is the case, it does not seem to translate into substantially higher use of such centres by female students. However, this evidence is consistent with suggestions in the literature that male students make more use of some online learning resources than women (Hoskins & van Hooff, 2005). It is worth pointing out that, in our study gender and discipline are confounded – there were proportionately more women mathematics students than engineering students, $\chi^2(1)=55.6$, $p<.001$ – so it is unclear whether

the differences we have observed here are driven primarily by gender, primarily by discipline, or primarily by some third factor related to both.

Do these Clusters Represent Genuinely Different Study Strategies?

To determine whether the differences in the behaviour between clusters reflected genuine differences in study strategies throughout the semester, or merely differences in last-minute revision strategies, we computed each participant's week-by-week (or, in the case of the LLs, lecture-by-lecture) cumulative access/attendance figures for each of the three study options. If the differences between the clusters were primarily due to differences in revision strategies we would expect to see a large between-clusters divergence in these figures towards the end of the modules. But, as Figure 2 clearly shows, the differences observed between the clusters were the result of consistently different study strategies throughout the semester. Consequently, we believe that a students' cluster-membership is a genuine reflection of their strategies for using the optional learning resources.

Insert Figure 2 about here

What is the Relationship between Study Strategy and Academic Achievement?

Students in the different clusters adopted significantly different strategies for their academic study. Were these differences in strategy related to their achievement in the end-of-module assessment? Because the engineering and mathematics undergraduates had slightly different diagnostic tests, and entirely different end-of-module examinations, we first standardised each participants' scores within their modules (i.e. we computed diagnostic test and examination z-scores separately for each module's cohort).

The standardised scores obtained by students on the diagnostic tests were subject to a one-way Analysis of Variance (ANOVA) with cluster-membership as the between-subjects factor.[3] There were no significant differences in incoming achievement between the clusters, $F<1$. To determine whether there were significant differences on the end-of-module examination we subjected the standardised examination scores to an Analysis of Covariance (ANCOVA) with cluster-membership as a between-subjects factor and standardised diagnostic test score as a covariate. There was a significant main effect of cluster-membership, $F(3,474)=12.7$, $p<.001$. Each cluster's mean standardised examination scores are shown in Figure 3. LSD post-hoc tests (using standardised residuals) revealed that Clusters 2 and 3 achieved significantly higher scores than both Clusters 1 and 4. There was no significant difference between Clusters 2 and 3, but a borderline significant difference between Clusters 1 and 4 in favour of Cluster 1 ($p=.091$).

In sum, the students whose strategy involved primarily attending LLs (Cluster 2) were the most successful in the end-of-module examination. Those students whose strategy involved average LL attendance but high MLSC attendance (Cluster 3) also performed well. The students whose strategy involved making little use of any of the three learning resources considered here (Cluster 4) performed the worst of the four clusters, suggesting that they probably were not making heavy use of any other learning resources either (for example, textbooks in the library, online forums etc.). Of particular interest was the performance of those students whose strategy involved often accessing the OLs (Cluster 1). They performed worse than either of Clusters 2 or 3, but better than Cluster 4.

To directly explore the extent to which using each of the learning resources contributed to success on the end-of-module examination we entered participants' standardised diagnostic test scores, and their access/attendance figures for LLs, OLs and the MLSC into a multiple regression with standardised end-of-module examination score as the dependent variable. We

first ran the regression analysis for the entire sample, and then individually for each cluster. The standardised coefficients associated with each independent variable are shown in Table 2.

Insert Table 2 about here

Across all participants the most important predictors of examination success were incoming diagnostic test achievement and attendance at LLs. The same was broadly true for each cluster. The only cluster whose diagnostic test scores were not related to final examination score was Cluster 3, the cluster who accessed the MLSC with above average frequency (although the overall model for this cluster was some way from reaching significance, so some care needs to be taken not to over-interpret this finding). Concerns about over-interpretation aside, this suggestive finding is consistent with claims in the literature that making heavy use of mathematics support mechanisms can disproportionately help students who enter university with relatively low achievement levels (Pell & Croft, 2008).

It is noticeable that MLSC attendance and OLs accesses were not positively associated with examination scores for any cluster (the betas for each did not approach significance on any analysis). There are at least two ways of interpreting this result. One interpretation would simply be to hypothesise that neither attending the MLSC nor viewing OLs is an effective way of learning mathematics. Although our findings are consistent with this interpretation, our study was not experimental – we did not randomly assign students to particular study strategies – so we cannot draw causal conclusions. A second interpretation comes from the observation that both OLs and the MLSC are 'on-demand' study resources: students could use them as many times as they wanted whenever they wanted (with some restrictions in the

MLSC's case). It might be reasonable to suppose, therefore, that some very heavy users of OLs and/or the MLSC were doing so because of a recognition that their understanding of the course content is suspect in some way. In other words, if weaker students use these study resources as a way of combating their poor understanding, the resources might be effective despite their usage figures not showing a relationship with end-of-module examination scores.

If the second hypothesis were correct then multiple regression analyses may not be a useful tool for assessing the efficacy of each study strategy (the second hypothesis essentially proposes a non-linear relationship between learning outcomes and both OL accesses and MLSC attendance). An alternative way of conceptualising the efficacy of each strategy is to consider what study strategies the four clusters would adopt in a traditional setting, where the only learning resource provided would be LLs. In particular, what would happen to Clusters 1 and 3 in such a situation? If OLs were withdrawn would those from Cluster 1 start attending LLs (i.e. move into Cluster 3) or would they substantially reduce their study time (move into Cluster 4)? A third possibility is that they would find alternative independent study resources (textbooks perhaps) and not join either cluster. If providing OLs reduces the number of students doing little or no academic work (i.e. reduces the number of students in Cluster 4), then it may be reasonable to conclude that they are an effective and valuable learning resource, even if they are less effective than attending LLs.

To explore this issue we calculated the mean marks of each participant on other modules (i.e. on every module they studied in the same academic year apart from the mathematics modules for which we compiled attendance data for). Because participants had a wide variety of different module choices, these data are by necessity noisy, so we did not attempt to compute standardised scores. These data are shown in Figure 4 and were subjected to a one-way ANOVA with cluster-membership as the between-subjects factor. There was a

significant effect, $F(3,470)=8.68$, $p<.001$. In other words, students' study strategies on their multivariate calculus module were related to their examination scores on the other modules they studied during the year. LSD post-hoc tests revealed that the between-cluster pattern of examination scores on other modules was broadly similar to those on the multivariate calculus modules. Cluster 2 had a significantly higher mean score than Clusters 1 and 4, and Cluster 3 had a significantly higher mean score than Cluster 4. The difference between Clusters 1 and 4, and 2 and 3 did not reach significance.

Insert Figure 4 about here

Under the assumption that the large majority of modules studied by participants were not supplemented with OLs (a reasonable assumption given the recent introduction of lecture-capture technology at Loughborough University during the year the study took place), these data allow us to tentatively address the question posed above. Namely, if OLs were not available, how would Cluster 1 behave? Although examination performance is clearly not a satisfactory proxy for study strategies, if Cluster 1 did attend LLs in modules where no OLs were available, we might have expected their mean examination performance to be closer to Cluster 2's. In fact their performance was significantly worse than Cluster 2's. This provides some indirect evidence for the suggestion that providing OLs does not lead to a dramatic decline in LL attendance or achievement, as feared by some higher education practitioners. However, further research would be required to substantiate this hypothesis. In particular, it would be valuable to compile attendance data for the same cohort of students in two courses: one where OLs are provided as part of a blended mix of learning resources, and one where only LLs are provided.

Summary and Conclusions

Providing students with multiple learning resources and allowing them to use as many (or as few) as they want is a hallmark of what have variously been called "blended", "HyFlex" or "hybrid" learning environments. Here we investigated individual differences in how students used three specific resources provided to them in the context of a multivariate calculus course: LLs, OLs and mathematics support. Contrary to our assumptions, and the assumptions of many blended learning enthusiasts, we found that there was not a large group of students who made above average use of more than one learning resource. Instead we found four clusters of students: those who often attended LLs, those who often accessed OLs, those who often attended the MLSC, and those who did not make heavy use of any of the three resources we considered. The study strategies adopted by students were related to their discipline of study and, contrary to Bassili's (2006) finding, to their academic success both on the module we studied and to the other modules they studied during the year. Those students who often attended the LLs or the MLSC were the most academically successful, with students who primarily learnt by accessing OLs being less successful. These findings are summarised in Figure 5.

Insert Figure 5 about here

There are at least two differences between the context of our study and that of Bassili's (2006) which might account for why we found a relationship between study strategy and academic success whereas he did not. First, we recorded actual usage data rather than self-report data. This is likely to have substantially reduced the noise in, and increased the validity of, our data compared to Bassili's. Second, we looked at students studying mathematics whereas Bassili considered psychology students. Several mathematicians have asserted that

lecturing is an especially effective mode of teaching in mathematics compared to other subjects. For example, Pritchard (2010) argued that modelling expert behaviour is an important role of a mathematics lecture, and that this cannot be effectively implemented without the informality and flexibility afforded by live interaction. In general, disciplinary differences in the efficacy of different study modes remains poorly understood.

Although we identified four different general strategies that students adopted, we do not have a good understanding of what drives these strategy choices. The philosophical basis of providing choice to consumers is that the consumers themselves are best placed to decide how to blend the available resources to achieve the best outcome. This assumption rests upon the belief that consumers, students in this case, can rationally assess the advantages and disadvantages of the various options they are provided with. Given our lack of firm knowledge about the efficacy of different teaching strategies, it is unclear how we expect our students to form such judgements. It would be a valuable goal for future research to determine how students decide on which strategies to adopt in blended learning environments, and to determine whether these are state characteristics (determined by, for example, students' beliefs about the quality of the lecturer or the convenience of the timetabling) or trait characteristics (determined by, for example, students' personality types or subject competence[4]). The similarities between the examination results obtained by the different clusters on the multivariate calculus module and other modules studied during the year hint that trait characteristics may be dominant. Despite substantial differences between the multivariate calculus module and students' other modules (in terms of, for example, the lecturer, the learning resources offered, and the convenience of the timetable), students' study strategies on the multivariate calculus course predicted their examination results on their other modules.

One under-appreciated consequence of devolving choice to students in the context of education is the reduction or removal of teachers' responsibilities to address metacognitive issues during their teaching. An explicit statutory requirement of undergraduate mathematics degrees in the UK is that they should attempt to develop students' "general study skills" (QAA, 2007). If this is the case, then explaining to learners what makes for an effective study strategy is surely part of the job of teaching mathematics in higher education. From this perspective, if learners are employing a suboptimal learning strategy then the teaching they are receiving is to some extent defective. It is highly unclear how this explicit requirement to develop students' study skills can fit with the belief that it is students themselves who are best placed to determine which study strategy would be most effective, and the growing trend to devolve such choices to students.

Perhaps the most surprising finding of this study is that students seem only to make above average use of one learning resource (or none). Again, understanding the reasons for this would be a valuable contribution to research. Perhaps, as suggested by some, students need explicit guidance in how to combine learning resources into an effective study strategy, or perhaps adopting a combined approach introduces an unreasonable demand on students' time. Regardless of the reasons behind students' strategy choices, if by "blended learning" we mean that the learning experience of the student consists of a substantial mix of resources, then the moniker seems inappropriate. Instead perhaps "blended teaching" might be a more accurate description of what we observed.

Acknowledgements

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Notes

1.   The range of possibilities in providing OLs is great, varying from a simple live recording of the actual lecture to staged recordings involving explanations. These, for example, may only involve a recording of the instructors voice over PowerPoint or a live voice over recording with hand-writing.

2.   Prior to conducting each parametric analysis reported in the paper the data were assessed to see if the relevant test's assumptions were met (normality, homogeneity of variance etc.). They were in each case.

3.   Because cluster membership was not independent of participants' discipline, for each ANOVA reported below we also conducted an ANOVA which included discipline as a factor, on no occasions was there a main effect or interaction involving the discipline factor, so we have omitted further discussion.

4.   Although note that if subject competence were a trait variable that influenced the study strategy that students adopted in our study, it could not have been measured by the diagnostic test that our participants took at the start of their course (which was independent of cluster-membership).

Tables

Table 1. The mean (unstandardised) usage data for the four clusters.

Cluster	Online Lectures (mean number of lectures accessed)	Live Lectures (mean percentage of lectures attended)	MLSC (mean number of visits)
1	58.0	36.2%	0.39
2	15.6	82.5%	0.38
3	12.8	60.0%	9.25
4	6.3	31.0%	0.35

Table 2. Regression (standardised) coefficients, with Standardised Examination Scores as dependent variable. Separate analyses are shown for the overall sample, and for each cluster individually. † p<.1, * p<.05, ** p<.01, *** p<.001. ‡ The overall model was not significant (p=.10).

Indep Var	β (Overall)	β (Cluster 1)	β (Cluster 2)	β (Cluster 3)‡	β (Cluster 4)
Standardised Diagnostic score	+.288***	+.418**	+.390***	+.033	+.262***
Live lecture attendance	+.325***	+.240†	+.208***	+.298*	+.129
MLSC use	+.020	+.110	+.065	-.196	+.063
Online lecture use	+.026	-.115	+.031	+.026	+.048

Figures

Figure 1. The mean standardised access/attendance data for the four clusters. Error bars show ±1 SE of the mean.
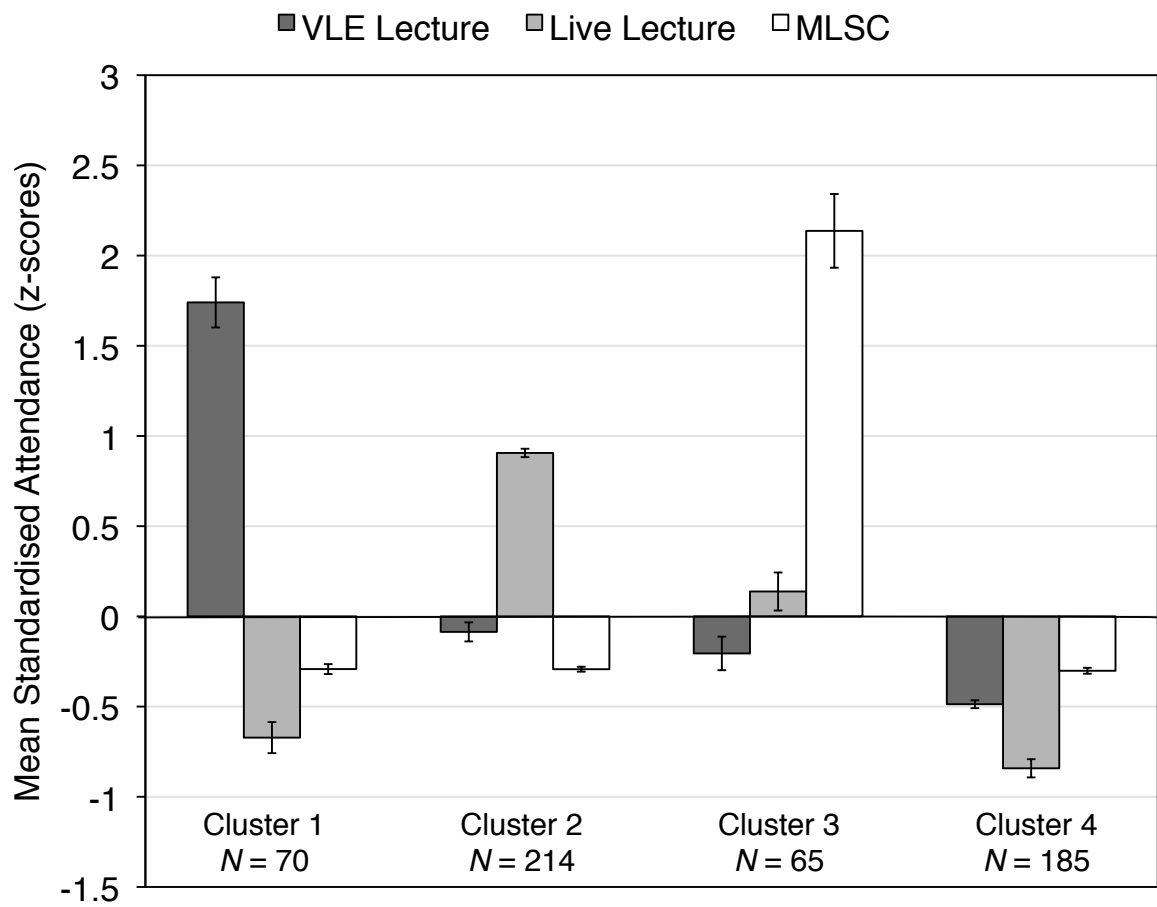
Figure 2. The cumulative access/attendance data of the four clusters for (a) online lectures, (b) live lectures and (c) the MLSC. The online lectures graph includes data for the five-week mid-semester break, during which time the MLSC was shut. Lecture-by-lecture attendance data for the live lectures was only recorded for one of the three courses considered in the main analysis.
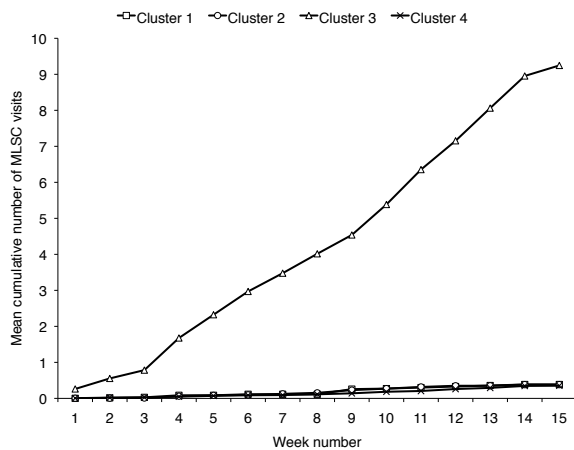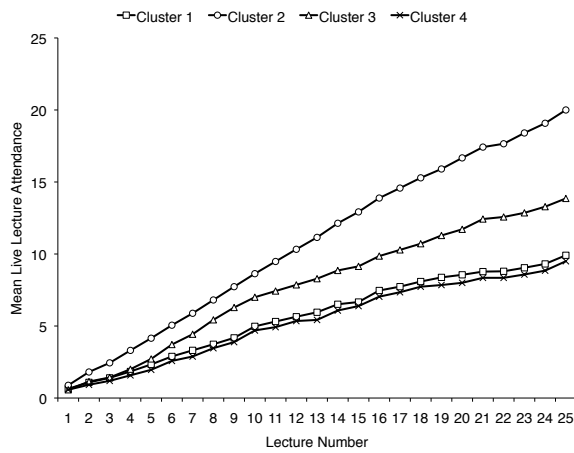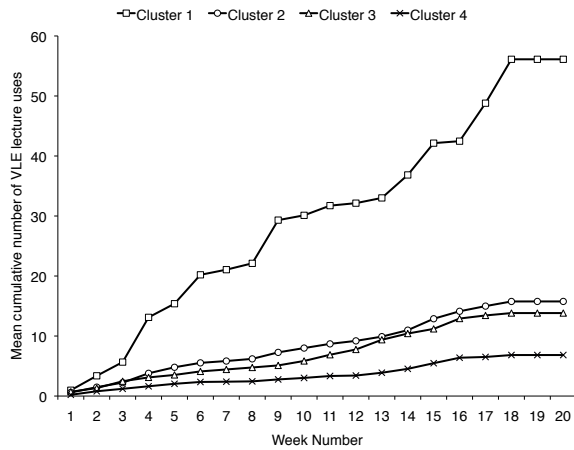
Figure 3. The mean standardised examination scores of the four clusters. Error bars show ±1
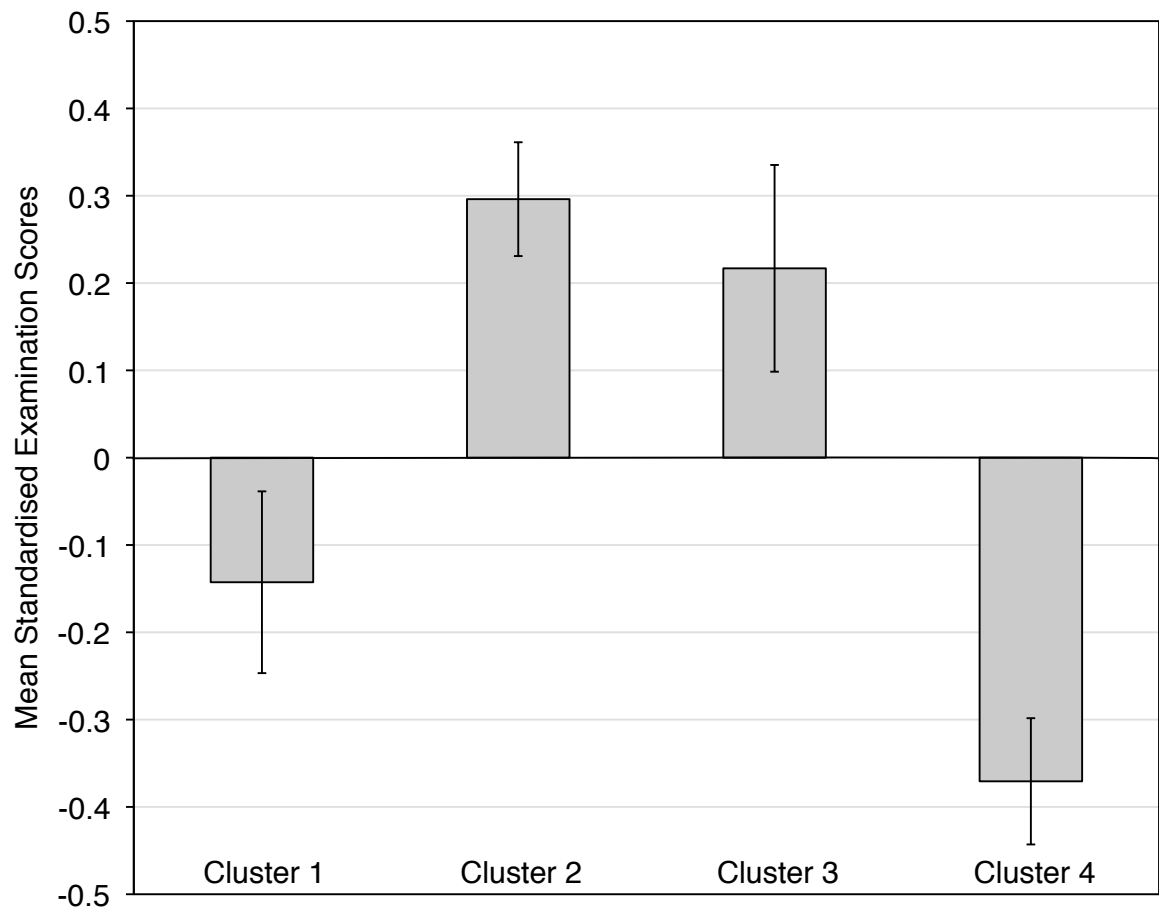
SE of the mean.

Figure 4. The mean examination scores of the four clusters on other modules taken during the year. Error bars show ±1 SE of the mean.
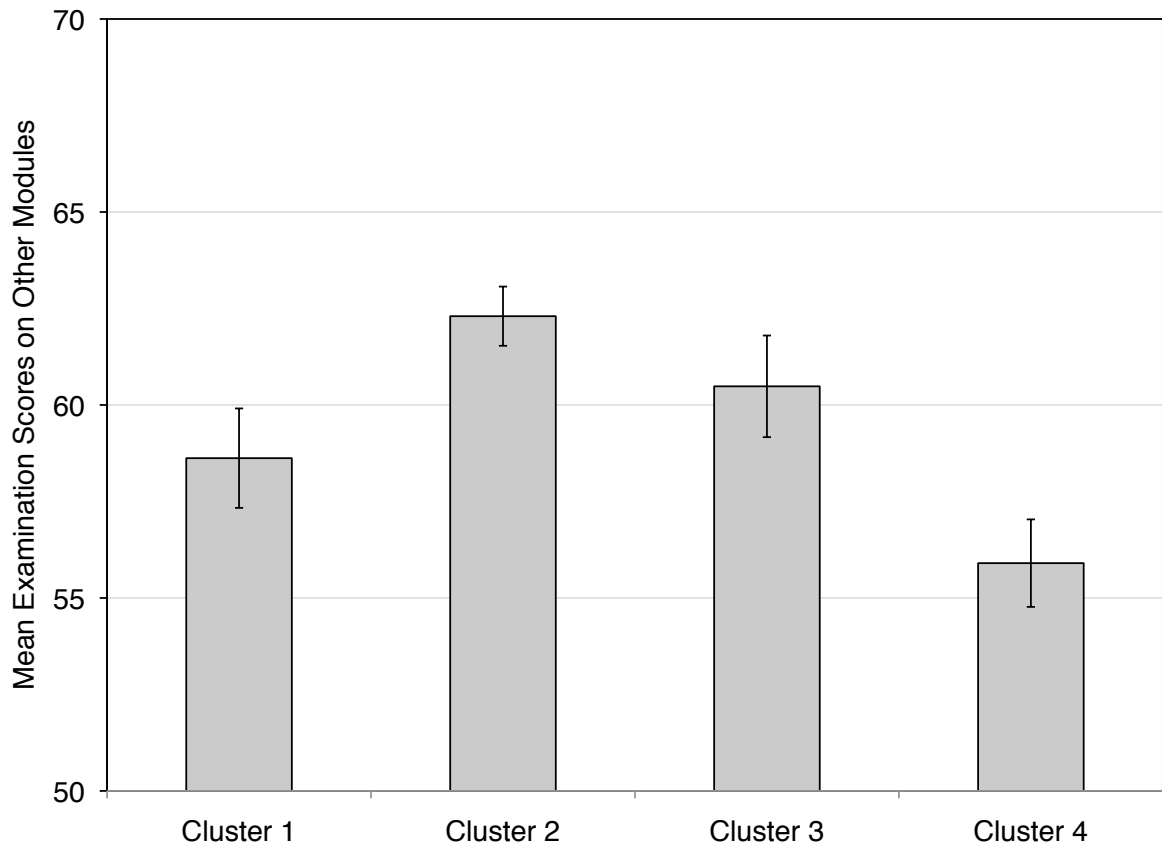
Figure 5. The mean standardised access/attendance data for the four clusters, together with their gender makeup (N_m and N_f showing male and female sample size respectively) and standardised examination scores (E). Error bars show ±1 SE of the mean.

	$N_m = 59$,	$N_m = 159$,	$N_m = 45$,	$N_m = 151$,
	$N_f = 11$,	$N_f = 55$,	$N_f = 20$,	$N_f = 34$,
	$E = -0.14$	$E = 0.30$	$E = 0.22$	$E = -0.37$