Improving the accessibility of foundation statistics for undergraduate business and management students using a flipped classroom

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A quantitative study was undertaken to investigate the accessibility of an undergraduate foundation statistics module for business and management students over four consecutive years, before and after the adoption of a flipped classroom teaching approach for a large cohort (~ 500 students per year). Students' module feedback questionnaires, exam scores, basic student demographics and online engagement and attendance data were analysed. Those taught using the flipped classroom approach found the module significantly more interesting and the proportion of students who perceived the module to be difficult was roughly half that under the traditional teaching approach. However, there was no evidence of a difference in exam performance, class attendance or online engagement under the two teaching approaches. Perceptions of the flipped classroom differed according to gender, nationality and reported prior maths training, but the flipped classroom appears to enhance the student experience by making a traditionally difficult subject feel more accessible.

(Abstract word count: 150 words)

Keywords: flipped classroom, blended learning, statistics, analytics, active learning.

(Paper word count: 7109 words)

Introduction

With the development of online learning technologies for distance-learning, there has been a move towards incorporating these tools into traditional classroom-based university teaching. In particular, recent years have seen the rise of the flipped classroom, a blended learning approach which moves lecture content out of the classroom and online, freeing up class time for more active learning methods. Abeysekera and Dawson (2015, p. 3) define the flipped classroom as "*a set of pedagogical approaches that:*

1. *move most information-transmission teaching out of class*
2. *use class time for learning activities that are active and social and*
3. *require students to complete pre- and/or post-class activities to fully benefit from in-class work.*"

As the traditional lecture content moves online, scheduled face-to-face teaching time can then be used for active learning methods (Baepler, Walker, and Driessen 2014), often utilising group discussions and problem-solving to explore application of the taught content. Learning is thus elevated from lower-order knowledge and comprehension to higher-order application, analysis, evaluation and synthesis in Bloom's taxonomy (Krathwohl 2002). As such, active learning is seen to have a more positive impact on student achievement than passive learning (Abeysekera and Dawson 2015).

Another perceived advantage of the flipped classroom is that, by allowing the students to study the lecture content online and in their own time, it gives students more flexibility and control over their learning pace (Forsey, Low, and Glance 2013; Baepler, Walker, and Driessen 2014; Abeysekera and Dawson 2015), enabling them to take responsibility for their own learning. In turn, students must be prepared for class in order to be able to participate in the active learning element (Forsey, Low, and Glance 2013; Gross et al. 2015; Moraros et al. 2015).

A number of mostly small-scale studies have been carried out over the past decade across a range of STEM and social science disciplines. Most studies have shown benefits to using the flipped classroom, including improved student perceptions of their engagement levels (Baepler, Walker, and Driessen 2014; Khanova et al. 2015; Moraros et al. 2015; O'Flaherty and Phillips 2015; Seery 2015) and more effective use of classroom time, leading to benefits in cost and efficiency (Mason, Shuman, and Cook 2013; Baepler, Walker, and Driessen 2014; O'Flaherty and Phillips 2015).

However, there have also been some mixed results. While some studies showed that students appreciated the increased flexibility of the flipped classroom (Baepler, Walker, and Driessen 2014; Gilboy, Heinerichs, and Pazzaglia 2015; Moraros et al. 2015; Nouri 2016), it was also shown that students need a clear structure, both in the presentation of the taught content and in the timings of study requirements (Strayer 2012; Mason, Shuman, and Cook 2013; Kim et al. 2014; Khanova et al. 2015; O'Flaherty and Phillips 2015). Additionally, the flipped classroom, more than the traditional classroom, requires student commitment and self-discipline (Strayer 2012; Kim et al. 2014; Abeysekera and Dawson 2015; Khanova et al. 2015; Moraros et al. 2015; Wanner and Palmer 2015).

While the flipped classroom has been associated with a significant improvement in student assessment results in some studies (Mason, Shuman, and Cook 2013; Missildine et al.

2013; Wilson 2013; Gross et al. 2015; Gonzalez-Gomez et al. 2016), other studies have found no such improvement (McLaughlin et al. 2013; Moraros et al. 2015; O'Flaherty and Phillips 2015), although it is generally concluded that the flipped classroom does not have a negative effect on student achievement. Similarly, while several studies state that students reported a considerable increase in workload (Missildine et al. 2013; Khanova et al. 2015; Wanner and Palmer 2015), Mason, Shuman, and Cook (2013) found that students reported a reduction in their workload compared with traditional teaching. However, the majority of studies found the workload of staff members involved in the flipped classroom to be greatly increased (Mason, Shuman, and Cook 2013; McLaughlin et al. 2013; Gilboy, Heinerichs, and Pazzaglia 2015; O'Flaherty and Phillips 2015; Wanner and Palmer 2015).

Although there have been a number of studies published to evaluate the flipped classroom approach to teaching, there remain many unanswered questions. The majority of studies that measure student engagement do so through qualitative analysis of student evaluation surveys, thus assessing student *perceptions* of engagement, which may differ to *actual* engagement. Measures of actual engagement include online activity (O'Flaherty and Phillips 2015) and class attendance rates, which can be subjected to quantitative analysis. Similarly, although a few studies have collected and analysed student demographics such as gender, grade point average (GPA) and ethnicity (Baepler, Walker, and Driessen 2014; Gross et al. 2015; Moraros et al. 2015), there are still questions around whether certain demographic groups benefit more from the flipped classroom than others. Strayer (2012) and Mason, Shuman, and Cook (2013) argue that the flipped classroom format is not suitable for first-year undergraduates due to a lack of maturity and self-discipline. However, there is a lack of large-scale research to support this assertion. Similarly, although O'Flaherty and Phillips (2015) and Wanner and Palmer (2015) argue the importance of giving course leaders access to technical support, few studies have utilised a dedicated e-learning team.

Background to this study

In this paper, we evaluate the effects of flipping the classroom for a core introductory statistics course delivered to first year business and management undergraduates at a highly-ranked UK business school. The course runs over ten weeks in term 1 of the academic year and has been led and taught by the same lecturer since 2013. The size of the cohort grew from around 480 students in 2013 to 590 in 2016. In 2015, the number of students enrolled on the course surpassed the capacity of the largest lecture theatre on campus, prompting the need

to think about innovative ways to deliver the module and resulting in the decision to flip the classroom. The course syllabus and the content and appearance of the lecture slides have remained the same since 2013, helping us to make sensible comparisons over time.

Due to the size and diversity of the cohort, teaching this course poses a number of challenges. The cohort is extremely multicultural. This results in a variety of expectations and previous academic experiences, many of which are driven by cultural factors. Furthermore, while some students have prior qualifications in mathematics or statistics (A-level or equivalent), other students have only a basic qualification in mathematics (GCSE or equivalent), generally obtained two or more years ago. We have tended to find that these students often lack confidence with quantitative subjects and, in some cases, are fearful of them. Teaching therefore needs to balance the needs of the less-confident and less-quantitative students with the requirement to engage the more-experienced students who may already have studied many of the core topics. Moreover, in our experience, first year undergraduate students do not necessarily appreciate the relevance of a statistics course to a business degree, or to their intended career path, and often struggle to grasp the real-world applications.

The principal aim of this study was to test the theory that the flipped classroom approach to teaching foundation-level statistics to business and management students makes the subject more accessible, with an emphasis on large cohorts. In this context, accessibility is evaluated by looking at the perceived difficulty of the course, as well as student engagement, interest and exam performance. Additionally, student demographic data is analysed to determine whether there is evidence that some groups of students find the flipped classroom more accessible than others, thus allowing us to consider tailored interventions to enhance the student experience in the future.

The traditional approach to teaching

Prior to flipping the classroom, the statistics module was taught in a traditional way. Over nine weeks the students attended two fifty-minute lectures per week and a fifty-minute small-group tutorial session. Lectures were delivered to the full cohort in the University's largest lecture theatre and tutorial sessions were run by graduate teaching assistants, referred to as tutors, in groups of approximately 20. Students were given a set of exercises before each tutorial session and were instructed to attempt them before attending, although feedback from

the tutors indicated that not everyone did. Two one-hour drop-in sessions were available each week, staffed by a tutor, to provide one-to-one support.

Materials for the module including lecture slides, tutorial exercises and solutions, and recordings of the lectures (audio and slides), were made available on the School's virtual learning environment.

The evolution of the module

The current lecturer began teaching the module in the 2013/14 academic year. At that point, assessment was through a single 90-minute open-book examination held in May. For extra support, in addition to the weekly drop-in sessions, an online forum was set up for students to post queries. This proved popular during the term, and particularly in the run-up to the exam, and has continued to be used each year.

In response to student feedback, the exam weighting was reduced to 95% in 2014/15 by introducing a class test worth 5%, taken halfway through the module. A second class test was introduced the following year, taken at the end of the teaching term, further reducing the exam weighting to 90%. To accommodate the large cohort, the class tests are undertaken remotely using the online testing software Questionmark Perception 5. To minimise the chance of collusion, the tests are time-limited and the questions are randomised.

Flipping the classroom

Although incremental improvements were being made to the module, a big push to innovate came when the School announced an anticipated increase of 100 students to the 2015/16 intake, taking numbers beyond the size of the largest lecture theatre. Maintaining the traditional module structure could have been achieved through double-teaching (i.e. delivering each lecture twice to half of the cohort in each sitting), but this felt unsatisfactory both from a pedagogical point of view and, more practically, from a staffing and timetabling perspective. Since the flipped classroom approach had been trialled in the School on an undergraduate module for 300 students a few months previously (Johnson, Chakkol, and Finne 2015), and had received positive feedback, it presented an appealing way forward.

A comparison of the traditional and flipped classroom approaches to teaching the introductory statistics module is given in Table 1. Flipping the classroom presented an opportunity to place more emphasis on smaller group activities designed to explore and reinforce concepts. Lectures were broken up into self-contained topics with a mean video

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length of 23 minutes. This was to ensure that students could watch each part in a standalone fashion, and to maintain a logical structure to the recordings with each video having a defined start and end point. As such, the mean length of 23 minutes was driven by the natural breaks in the material, and not wholly by the intention to produce videos of a particular length. Having said that, we also felt that the videos needed to be shorter than a standard face-to-face lecture to keep the attention of the viewer.

The videos were recorded as screencasts using TechSmith Camtasia Studio 8 and used the same PowerPoint slides as in the traditional classroom. Each had an audio voiceover from the lecturer and real-time hand-written annotations of worked examples made using a Wacom Cintiq 22HD graphics tablet. The screencasts were recorded in a dedicated studio and the files were subsequently edited by the e-learning team to ensure a high production quality. The video output was 700x525 pixel MP4 files with a bitrate of 2048 Kbits which were hosted on Vzaar and embedded in the module VLE. Approximately two hours of videos are uploaded to the School's virtual learning environment each week during the teaching term and students are expected to watch them before attending small-group classes, just as they would have been expected to attend lectures in the traditional approach.

As previously, students attend a weekly tutorial session. However, exercises are given out during the sessions rather than beforehand and are attempted in small groups of 4 or 5 before sharing ideas with the class. This removes the need for preparation beforehand (other than watching the lectures) and is intended to encourage participation and engagement. Twice during the term, the students attend a workshop with the lecturer in place of their usual weekly tutorial. The workshops contain around 75 students and are supported by two or three tutors. These sessions were introduced to allow the students smaller-group access to the lecturer and an opportunity to clarify any doubts. The use of the flipped classroom, and the general running of the module, is supported by a dedicated e-learning team.

Online forums were available in both teaching formats across all four years. Students are encouraged to interact with each other on the forums, but they are principally managed by the lecturer to ensure queries are answered correctly.

[Table 1 here]

Methods

Research design and data collection

A quasi-experimental design was used for this study to compare the experiences of students before and after flipping the classroom. Students taking the module in the 2013/14 academic year taught using the traditional lecture-based approach, and those taking the same module in 2015/16 and 2016/17 using the flipped classroom approach, were asked to complete an end of term module feedback questionnaire. The questionnaires were completed on paper during tutorial sessions towards the end of term. Feedback data specifically for this study was not collected in 2014/15. The questionnaires for the pre and post flipped cohorts contained some common questions to ascertain opinions on the module, and the post-2015 questionnaires included additional questions specific to the flipped classroom.

In order to ascertain views on the module and the flipped classroom for different subgroups, baseline (admissions) data was obtained for the full student cohorts across all four years since 2013/14, including gender, programme of study and nationality. In addition, monitoring data was recorded, including exam score, attendance at small-group classes and engagement with online module resources.

To compare the accessibility of the subject under the traditional and flipped classroom modes of teaching, five outcomes were selected: interest in the module, perceived difficulty of the module, performance in the end of year module examination (exam score, %), attendance at tutorials (%) and online materials accessed (%). Interest and perceived difficulty were assessed for students who answered the respective feedback questions "Did you find the module interesting?" (yes/no) and "How difficult did you find the module?" ('very easy/easy/adequate' versus 'difficult/very difficult'). Additionally, data was gathered from students in 2015/16 and 2016/17 to determine whether they liked the flipped classroom mode of delivery (yes/no).

Full ethical approval to analyse the study data and publish the results was granted by the University Humanities and Social Sciences Research Ethics Committee (ref: 44/17-18).

Participants

The undergraduate cohort in the School is highly mixed in terms of nationality with less than a quarter of the students identifying as British, but the balance of genders is even. Students can enrol on a variety of degree programmes, including undertaking joint degrees with other

departments, but the two main programmes of study are Accounting and Finance (A&F) and Management. Over the four-year period of this study, the percentage of the cohort undertaking A&F has steadily decreased from 46.5% (220/473) in 2013/14 to 36.1% (213/590) in 2016/17, with intake to Management showing a steady increase from 31.7% (150/473) in 2013/14 to 38.8% (229/590) in 2016/17. However, the absolute number of students choosing A&F has remained consistent. Each year there is very little variability in academic performance on entry since students must achieve three A levels at grade A or higher (or equivalent) to gain a place, with a small number of exceptions. Those applying for A&F must have obtained an A level in Mathematics (or equivalent), with no such requirement for students taking the other degree programmes. The characteristics of the cohorts are summarised in Table 2.

Module feedback questionnaires were completed by 327/473 (69.1%) students in 2013/14, 455/552 (82.4%) in 2015/16 and 488/590 (82.7%) in 2016/17. The lower response rate in 2013/14 reflects the fact that the questionnaires were distributed in the last week of term when attendance tends to be poorer rather than the penultimate week, as for the later cohorts. As seen in Table 2, the characteristics of the feedback respondents are largely representative of the corresponding cohorts.

[Table 2 here]

Statistical analysis

Descriptive statistics were used to explore basic characteristics of the students, including frequencies with percentages and medians with interquartile ranges. The chi-squared test was used to compare proportions where relevant.

Logistic regression models were used to more thoroughly investigate factors predictive of interest, perceived difficulty and whether students liked the flipped classroom approach. A multiple linear regression model was used to investigate factors affecting exam score. The following baseline variables were considered in each of these models: year of study, gender, nationality and programme of study. Prior maths training at A level standard (yes or no) was considered in some of the models but not all since the information was only available for feedback respondents. In each case, a manual backward elimination approach was conducted to remove variables from the model one at a time based on significance at the 5% level. Any variables not included in the model were added back in one at a time to check their significance in the presence of other variables.

All analyses were completed using a complete case approach to deal with missing values, which means that sample sizes vary slightly by analysis. The analyses were undertaken using IBM SPSS Statistics 24.

Results

Basic perceptions of the module

Of those who completed a feedback questionnaire, 65.7% (n = 215) found the module interesting in 2013/14 under the traditional approach compared to 84.2% (n = 794) under the flipped classroom approach (P < 0.001, chi-squared test). Those taught using the flipped classroom also perceived the module to be less difficult with only 33.3% (n = 314) rating it as 'difficult or very difficult' compared to 63.0% (n = 206) taught using the traditional approach (P < 0.001, chi-squared test). The students were asked to rate the quality of the lecture slides in 2013/14 and the quality of the recorded lectures in 2015/16 and 2016/17. Bearing in mind that the content and appearance of the slides did not change between cohorts, just the format of delivery, 65.1% (n = 213) in 2013/14 rated the lectures as 'very good or excellent' compared to 85.2% (n = 803) in the flipped cohorts (P < 0.001, chi-squared test).

[Table 3 here]

Perceived interest and difficulty

After fitting separate logistic regression models to investigate factors influencing the two outcomes 'Found the module interesting' (yes or no) and 'Found the module difficult' (yes or no), the year of study, which also represents the mode of delivery, was found to be a significant predictor of both. Those in the two flipped cohorts were significantly more likely to find the module interesting and less likely to find it difficult than those in the 2013/14 traditional cohort, after adjusting for other factors. Prior maths training was also significant in both models indicating that those who have not undertaken such training are less likely to find the module interesting and more likely to find it difficult. None of the other baseline factors were found to have an influence on perceived interest, but nationality, gender and programme of study all appear to significantly influence perceived difficulty. Specifically, female students are more likely to perceive the module as difficult compared to male students (adjusted odds ratio 1.473, 95% confidence interval 1.125 to 1.928, P=0.005), as are those studying Management compared to A&F, even after adjusting for prior maths training

(adjusted odds ratio 1.737, 95% confidence interval 1.238 to 2.436, P=0.001). When compared to British 'home' students, French and Chinese students are significantly less likely to regard the module as difficult (P=0.005 and P=0.001 respectively). The results of the fitted logistic regression models are shown in Table 4.

[Table 4 here]

Performance

The distributions of exam scores for the four cohorts are compared in Figure 1 and the average exam scores (%) were as follows, (median; interquartile range): 2013/14 (65; 51.5 to 74), 2014/15 (72; 60.0 to 81.0), 2015/16 (66; 54.0 to 74.8), 2016/17 (60; 48.0 to 73.0).

A multiple linear regression model was fitted to further investigate the effects of the mode of delivery on exam performance, adjusting for baseline characteristics (Table 5). Whether a student had undertaken prior training in mathematics was only available for those who completed feedback and was therefore not included in the model. There were fluctuations in exam performance across the four years, but no strong evidence to suggest a difference in performance between those taught using the traditional delivery and those taught using the flipped classroom. Compared to the 2013/14 traditional cohort, the 2015/16 flipped cohort performed slightly better (P=0.042) while the 2016/17 flipped cohort performed slightly worse, although evidence for this is borderline (P=0.059). The 2014/15 traditional cohort stands out as a high performing group.

All nationality groups apart from Malaysian students had lower exam performance compared to British students, despite them generally perceiving the module to be less difficult (see Table 4). On the other hand, in line with perceptions of difficulty, Management students performed significantly worse than A&F students (P<0.001).

[Table 5 here]

Engagement

During the module, students are expected to attend eight face-to-face classes across the term. Under the traditional teaching, these were all small-group tutorials with a tutor. However, under the flipped classroom six of them are small-group tutorials and two of them are workshops with the lecturer that include the tutorial work. Figure 2 shows the percentage of students who attended each of the eight face-to-face sessions for all four cohorts.

Although there is some variation in attendance between the cohorts, it appears consistent under the two modes of teaching across the term. Attendance shows an overall downward trend for all cohorts, falling from between 93% and 96% at the start of term to between 71% and 77% in the last week of term. Comparing the two traditional cohorts with the two flipped cohorts, 677/908 (74.6%) of those taught using the traditional approach attended 7 or more of the face-to-face classes compared to 819/1142 (71.7%) of the flipped cohorts (P = 0.150, chi-squared test).

[Figure 2 here]

In terms of online engagement, bearing in mind that the volume and type of online materials uploaded to the School's module was different under the flipped and traditional approaches, the median percentage of the online module materials accessed by each student during the module (with interquartile range) was as follows: 2013/14, 72.4% (62.1 to 79.3); 2014/15, 93.3% (88.9 to 97.8); 2015/16, 81.9% (73.6, 90.3); 2016/17, 83.3% (73.6, 90.3). Online engagement is very consistent for the two flipped cohorts, but also high under the traditional teaching, particularly for the 2014/15 cohort.

Perceptions of the flipped classroom

Focusing on the 2015/16 and 2016/17 cohorts, the flipped classroom was well-received. A total of 366/455 students (80.4%) in 2015/16 and 389/488 (79.7%) in 2016/17 said they liked this mode of delivery.

To further investigate perceptions of the flipped classroom, a logistic regression model was fitted with 'Like flipped classroom' (yes or no) as the outcome of interest (Table 6). In the initial exploration of the data for the two flipped cohorts, and during the model building, it was apparent that nationality and programme of study are highly correlated. For instance, Malaysian students are almost exclusively enrolled to study A&F whereas Indian students are more likely to opt for Management. As such, to avoid issues of multicollinearity, a decision was made to include nationality in the model instead of programme of study, since this is a fixed characteristic. The final model contained both gender and nationality. Female students appear more likely to favour the flipped classroom than male students (adjusted odds ratio 1.736, 95% confidence interval 1.194 to 2.524, P=0.004). When compared to British students, although the other nationality groups were generally less in favour of the flipped

classroom, this effect was only significant for the French students (adjusted odds ratio 0.451, 95% confidence interval 0.255 to 0.796, P=0.006).

[Table 6 here]

Discussion

The main aim of this study was to investigate whether adopting a flipped classroom approach to teaching foundation-level statistics improves accessibility to the subject for first year undergraduate business and management students, as compared to a traditional lecture-based approach. We also evaluated whether those taught using the flipped classroom liked this mode of teaching and whether there are differences in perceptions of the module and the flipped classroom according to characteristics such as gender, nationality and chosen programme of study. This quantitative study has captured the characteristics and views of a very large cohort, thus adding robustness to the findings.

Comparing perceptions of the statistics module before and after flipping the classroom, there are clear differences, with those taught under the flipped classroom generally perceiving the module to be less difficult and more interesting. A total of 65.7% of students taught using the traditional lecture-based approach found the module interesting compared to 84.2% of those taught using the flipped classroom, while the percentage of those who found the module difficult or very difficult was much greater under the traditional approach; 63.0% versus 33.3%. These differences remain after adjusting for baseline student characteristics. The large reduction in students rating the module difficult combined with the increase in perceived interest suggests that a flipped classroom creates a feeling of greater accessibility. This is encouraging considering that statistics is a subject that often causes anxiety for students (Wilson 2013).

The flipped classroom cohorts also rated the quality of the lectures more highly, with 85.2% of the questionnaire respondents regarding the lectures as very good or excellent compared to 65.1% in the traditional cohort. While we cannot overlook the fact that the cohorts were taught in different years over a four-year period, and comparisons are therefore not made on a true like-for-like basis, these findings strongly suggest that flipping the classroom has led to improved perceptions of the module, which is in agreement with previous studies (Mason, Shuman, and Cook 2013; Baepler, Walker, and Driessen 2014; Moraros et al. 2015). This is supported further by the fact that the lecturer remained the same

over the four years, with consistently high teaching ratings, and both the syllabus and appearance and content of the lecture slides did not change.

However, in line with some previous studies (McLaughlin et al. 2013; Moraros et al. 2015; O'Flaherty and Phillips 2015) and contrary to others (Mason, Shuman, and Cook 2013; Missildine et al. 2013; Wilson 2013; Gross et al. 2015; Gonzalez-Gomez et al. 2016), we found no evidence of a positive impact of the flipped classroom on student exam performance, with average exam scores remaining broadly consistent across the four years. As such, while students appear to find the module easier with a flipped classroom, this does not translate to improved assessment performance. However, nor does it decline, which is in agreement with the general finding that the flipped classroom does not have a negative impact (Mason, Shuman, and Cook 2013; Baepler, Walker, and Driessen 2014; Gonzalez-Gomez et al. 2016). Of course, this does not consider less tangible aspects of achievement such as enhanced problem-solving and critical thinking skills (Moraros et al. 2015; O'Flaherty and Phillips 2015), and a clearer understanding of the real-world applications of the subject.

Strayer (2012) and Mason, Shuman, and Cook (2013) suggested that the flipped classroom approach is unsuitable for first-year students due to a lack of maturity and self-discipline. However, our findings challenge this since 80% of the flipped cohort respondents reported that they liked this mode of delivery, thus implying that they felt able to handle the demands of this learning approach. Anecdotally, some students commented in the feedback questionnaires that the lack of a fixed lecture timetable made it harder for them to structure their time, but a greater number commented that they appreciated the flexibility of the flipped classroom approach. Although not included in the main analysis for this study, this is in agreement with results from previous studies (Baepler, Walker, and Driessen 2014; Gilboy, Heinerichs, and Pazzaglia 2015; Moraros et al. 2015; Nouri 2016) and deserves further investigation in future work.

Attendance at tutorials was at similar levels and declined at a similar rate during the term for all four cohorts, suggesting that flipping the classroom did not in itself lead to a drop-off in face-to-face engagement. Indeed, the minimum attendance rate was above 70%, with the lowest rate in 2014/15 under the traditional approach. Lecture attendance data is not routinely collected so it is not possible to compare lecture attendance rates under the traditional teaching approach with online lecture viewing rates for the flipped classroom.

However, engagement with online materials was very consistent for the two flipped cohorts with the students accessing, on average, just over 80% of the uploaded materials during the module. Although this is a crude measure of online engagement, it provides some reassurance that the students take some responsibility for their learning.

The analysis revealed differences in perceptions across different subgroups. In terms of gender, there is evidence that the flipped classroom approach is more favourably received by female students, despite them perceiving the module to be more difficult than their male peers. A total of 85.3% of females (384/450) said they liked the flipped classroom compared to 77.2% of males (366/474). However, there is no evidence of a difference in exam performance between the genders, regardless of the mode of teaching.

Focusing on nationality, French and Chinese students perceive the module to be less difficult than do their British 'home' counterparts. However, performance in the final exam is significantly worse for all nationality groups compared to the home students (except for Malaysian students who perform highly), with French students receiving the lowest average marks overall. After adjusting for other factors, French students score on average 10 marks less (out of 100) in the final exam than their British peers, regardless of the mode of delivery. This analysis highlights an important mismatch between perceptions of difficulty and performance in some nationality groups which are not accounted for by the mode of teaching. This disparity poses a particular challenge when designing tailored interventions for struggling students which require them to recognise the need for additional help.

Students who reported prior mathematics training (A level or equivalent) were more likely to find the module interesting and less likely to find it difficult than students without such training. Although we were not able to thoroughly investigate the effects of prior quantitative training on exam performance, the chosen programme of study goes some way to exploring this. A level mathematics (or equivalent) is a pre-requisite entry qualification for those undertaking the more numerical Accounting and Finance degree but not for the other degree programmes. Focusing on A&F and Management students, there is evidence of differences in perceived difficulty and exam performance. Management students find the module more difficult than A&F students and score on average 6 marks less (out of 100) than the A&F students in the module exam, after adjusting for other characteristics. However, there was no significant difference in favourable opinion of the flipped classroom. Evidencing the need for additional support for those from a non-mathematical background

studying foundation statistics is no revelation. However, it is interesting to discover that the flipped classroom approach to teaching does not appear to disadvantage those students.

Limitations and further research

Although culturally diverse, the intake to this prestigious business school is highly selective in terms of academic achievement. Further research is therefore needed to establish whether active learning approaches such as the flipped classroom would be received in the same way in more academically diverse groups. As mentioned above, we were also unable to compare cohorts in a true like-for-like fashion, so could not account for all changes over time which may influence a student's learning experience, although we did attempt to control for this as far as possible. However, this large-scale quantitative study provides an in-depth and rich evaluation of the flipped classroom approach to teaching foundation statistics, the likes of which is currently lacking.

Future work is needed to better understand how and when students engage with online resources in a flipped classroom environment. It would also be instructive to analyse whether a flipped classroom enhances problem-solving and critical thinking skills, thus providing an enhanced understanding of the real-world applications of the subject.

Conclusion

Whether the flipped classroom improves accessibility does, to a large extent, depend on institutional priorities. We found no evidence that it leads to improved exam performance, nor that it encourages increased attendance at face-to-face sessions. That said, it did not appear to hinder performance either. However, our findings suggest that within the flipped classroom, students perceive the subject to be less difficult and more interesting, thus making the material feel more accessible. This, by extension, enhances the student experience which is an important aim for institutions in an age of high student fees and university rankings. It is also encouraging to observe for such a large cohort the positive shift in perceptions towards a subject which is often a source of anxiety for students (Wilson 2013).

There is a significant amount of input required to create a good flipped classroom and the use of an e-learning team to produce professionally-edited video content and provide context-specific consultation is advised. However, once developed, the content can be used across multiple years and the overall positive reception from students rewards the extra work required upfront.

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Table 1. Comparison of the traditional and flipped classroom approaches to teaching the foundation statistics module

Module component	Traditional	Flipped classroom
Lectures	2 x 50-minute lectures per week in lecture theatre over nine weeks. Total lecture time = 900 mins	1 x 50-minute live lecture plus 38 videos recorded using TechSmith Camtasia Studio 8, released online over eight weeks. Mean video length 23 minutes. Total lecture time = 939 mins
Tutorials	1 x 50-minute tutorial per week with tutor over eight weeks. Preparation expected ahead of session. Total tutorial time = 400 mins	1 x 50-minute tutorial per week with tutor over six weeks. No preparation expected ahead of session. Total tutorial time = 300 mins
Workshops	None	2 x 110-minute workshops with lecturer, supported by at least two tutors. No preparation expected ahead of session. Total workshop time = 220 mins
Extra support: Self-assessment exercises	None	8 exercise sheets with solutions for self-study issued across the term, one per week.
Extra support: Drop-in sessions	2 x 1-hour drop-in sessions per week over eight weeks, run by a tutor.	1 x 1-hour feedback and support session per week over eight weeks, run by lecturer.
Extra support: Online forum	Available all academic year	Available all academic year

Table 2. Characteristics of cohorts and feedback respondents: 2013/14 to 2016/17

Characteristic	2013/14		2014/15	2015/16		2016/17	
	Cohort (n=473)	Respondents (n=327)	Cohort (n=435)	Cohort (n=552)	Respondents (n=455)	Cohort (n=590)	Respondents (n=488)
Gender; n (%)							
Male	248 (52.4%)	161 (49.2%)	217 (49.9%)	286 (51.8%)	228 (50.1%)	313 (53.1%)	251 (51.4%)
Female	225 (47.6%)	160 (48.9%)	218 (50.1%)	266 (48.2%)	222 (48.8%)	277 (46.9%)	231 (47.3%)
Missing	-	6 (1.8%)	-	-	5 (1.1%)	-	6 (1.2%)
Prog of study; n (%)							
A&F	220 (46.5%)	166 (50.8%)	192 (44.1%)	227 (41.1%)	201 (44.2%)	213 (36.1%)	173 (35.5%)
Management	150 (31.7%)	108 (33.0%)	135 (31.0%)	196 (35.5%)	146 (32.1%)	229 (38.8%)	190 (38.9%)
Other	103 (21.8%)	52 (15.9%)	108 (24.8%)	129 (23.4%)	106 (23.3%)	148 (25.1%)	121 (24.8%)
Missing	-	1 (0.3%)	-	-	2 (0.4%)	-	4 0.8%
Nationality; n (%)							
British	115 (24.3%)	65 (19.9%)	105 (24.1%)	105 (19.0%)	78 (17.1%)	137 (23.2%)	97 (19.9%)
Chinese	59 (12.5%)	37 (11.3%)	61 (14.0%)	60 (10.9%)	43 (9.5%)	66 (11.2%)	42 (8.6%)
French	55 (11.6%)	22 (6.7%)	59 (13.6%)	86 (15.6%)	75 (16.5%)	101 (17.1%)	85 (17.4%)
Indian	37 (7.8%)	26 (8.0%)	25 (5.7%)	64 (11.6%)	42 (9.2%)	50 (8.5%)	34 (7.0%)
Malaysian	51 (10.8%)	30 (9.2%)	58 (13.3%)	69 (12.5%)	54 (11.9%)	46 (7.8%)	32 (6.6%)
Other	156 (33.0%)	73 (22.3%)	127 (29.2%)	168 (30.4%)	120 (26.4%)	190 (32.2%)	154 (31.6%)
Missing	-	74 (22.6%)	-	-	43 (9.5%)	-	44 (9.0%)

Table 3. Perceptions of the module across three cohorts, including combined totals for those who were taught using the flipped classroom approach; n (%)

Perception of the module	Traditional	Flipped classroom		
	2013/14 (n=327)	2015/16 (n=455)	2016/17 (n=488)	2015 to 2017 (n=943)
Interesting	215 (65.7%)	387 (85.1%)	407 (83.4%)	794 (84.2%)
Difficult or very difficult	206 (63.0%)	142 (31.2%)	172 (35.2%)	314 (33.3%)
Quality of lectures: very good or excellent	213 (65.1%)	392 (86.2%)	411 (84.2%)	803 (85.2%)

Table 4. Logistic regression analyses to look at perceived interest (n=1259) and perceived difficulty (n=1102)

Variable	Module interesting (yes or no, ref = no)			Perceived difficulty (very easy/easy/adequate or difficult/ very difficult) (ref = very easy/easy/adequate)		
	Adjusted OR (95% CI)		P value	Adjusted OR (95% CI)		P value
Cohort (ref = 2013/14)						
2015/16	2.888	(2.035, 4.097)	< 0.001	0.298	(0.211, 0.422)	< 0.001
2016/17	2.690	(1.919, 3.770)	< 0.001	0.328	(0.233, 0.461)	< 0.001
Prior maths (ref = no)	1.705	(1.194, 2.433)	0.003	0.294	(0.203, 0.427)	< 0.001
Gender (ref = male)	-	-	-	1.473	(1.125, 1.928)	0.005
Nationality (ref = British)						
Chinese	-	-	-	0.414	(0.248, 0.694)	0.001
French	-	-	-	0.521	(0.330, 0.825)	0.005
Indian	-	-	-	0.984	(0.589, 1.643)	0.950
Malaysian	-	-	-	0.850	(0.514, 1.404)	0.525
Other	-	-	-	0.503	(0.348, 0.728)	< 0.001
Programme of study (ref = A&F)						
Management	-	-	-	1.737	(1.238, 2.436)	0.001
Other	-	-	-	1.221	(0.812, 1.836)	0.337

OR=odds ratio; 95% CI= 95% confidence interval;

ref = reference category against which other categories are compared

Table 5. Multiple regression analysis to investigate performance, assessed using exam scores (%); n=2023

Variable	Estimated coefficient; (95% CI)		P value
Cohort (ref = 2013/14)			
2014/15	7.17	(5.21, 9.14)	< 0.001
2015/16	1.92	(0.07, 3.78)	0.042
2016/17	-1.76	(-3.59, 0.07)	0.059
Nationality (ref = British)			
Chinese	-3.72	(-6.08, -1.36)	0.002
French	-10.31	(-12.61, -8.00)	< 0.001
Indian	-5.21	(-7.90, -2.52)	< 0.001
Malaysian	1.36	(-1.15, 3.87)	0.288
Other	-2.17	(-3.99, -0.34)	0.020
Programme of study (ref = A&F)			
Management	-6.29	(-7.96, -4.62)	< 0.001
Other	-6.19	(-8.10, -4.28)	< 0.001

CI= 95% confidence interval;

ref = reference category against which other categories are compared

Table 6. Logistic regression analysis to investigate whether those taught using the flipped classroom liked this mode of teaching (n=848)

Variable	Liked the flipped classroom (yes or no, ref = no)		P value
	Adjusted OR (95% CI)		
Gender (ref = male)	1.736	(1.194, 2.524)	0.004
Nationality (ref = British)			
Chinese	1.273	(0.538, 3.010)	0.582
French	0.451	(0.255, 0.796)	0.006
Indian	0.623	(0.305, 1.275)	0.195
Malaysian	0.892	(0.419, 1.897)	0.767
Other	0.675	(0.397, 1.149)	0.147

OR = odds ratio; 95% CI = 95% confidence interval;

ref = reference category against which other categories are compared

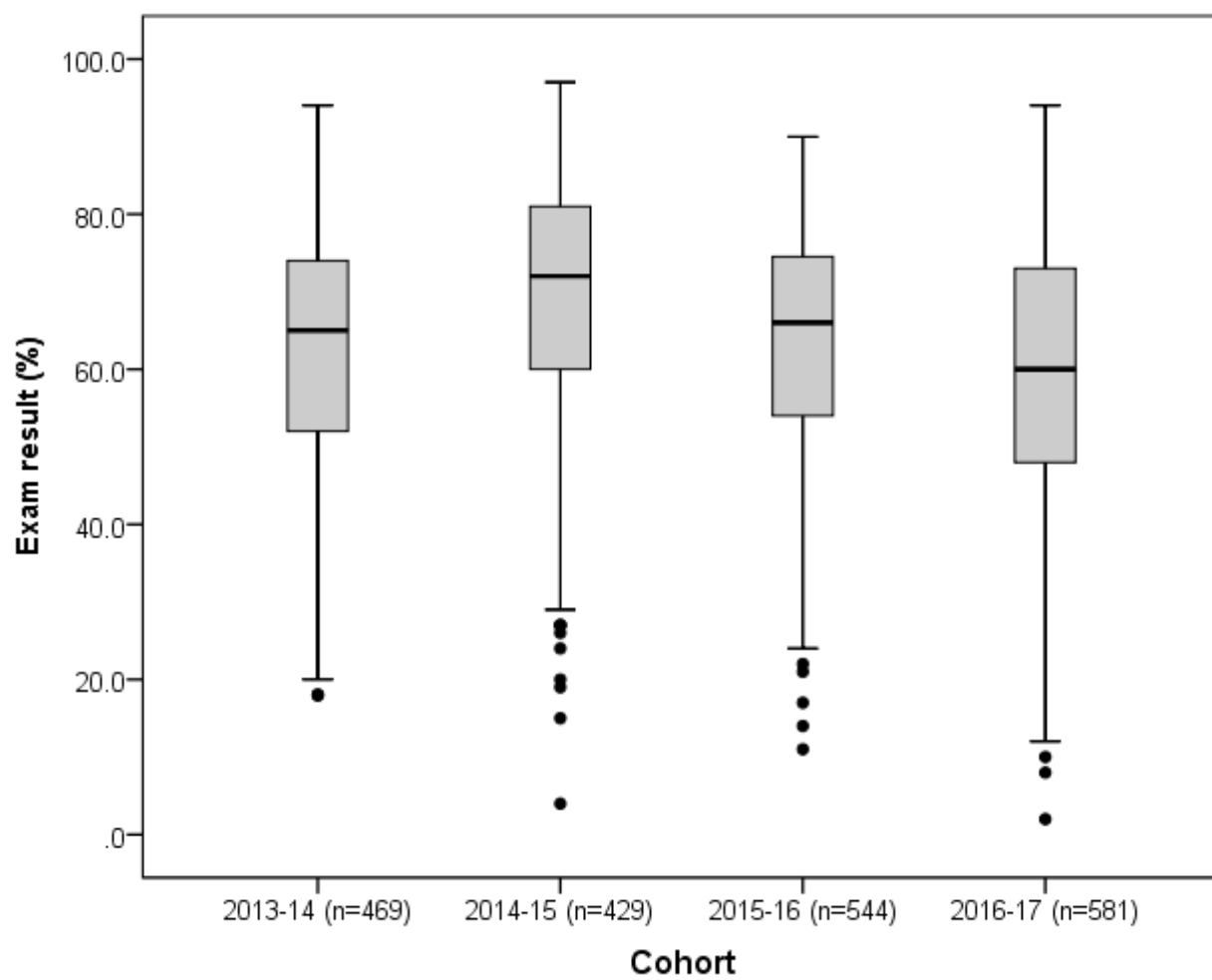Figure 1. Module exam scores across four years

Figure 2. Percentage of students attending each face-to-face class across the teaching term over four years