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Insights Gained from Analysis of Performance and Participation in a Flipped Classroom

Melinda R. Hodkiewicz†

The University of Western Australia

A flipped classroom uses technology to move lectures outside the classroom reserving the time inside the classroom for learning activities that connect concepts with practice. There has been limited research looking at student behaviours in a flipped learning environment and the extent to which students actually prepare for the face to face workshop experience as anticipated in the flipped learning model. Data collected from the learning management system (LMS) is used to examine the relationship between participation in pre-workshop activities and performance in a flipped learning class. The study cohort is a large class of final year bachelor and master of engineering students studying Risk, Reliability and Safety. Results show that participation associated with looking at pre-workshop materials and engaging in discussion boards is positively related to performance in summative assessments. There are lower levels of participation by international students in pre-work and discussion boards compared to their domestic counterparts; this may be related to language and the need to improve 'engineering business' skills. This work shows how technology, in the form of the data on participation collected in the LMS, can also be used to examine student behaviour, inform flipped learning teaching practice and identify future research questions.

Introduction

Learning management systems (LMS) are now commonly used in higher education. Combined with the ability of students to access these systems from anywhere, anytime through smart phones, tablets and computers, the question of how to best utilise these system to improve students' learning experience has been exercising the minds of educators. One approach is to use the LMS to introduce students

† Address for correspondence: Professor Melinda Hodkiewicz, School of Mechanical and Chemical Engineering, The University of Western Australia (M050), 35 Stirling Highway, Crawley WA 6009. Email: Melinda.Hodkiewicz@uwa.edu.au.

to course content outside of the classroom so as that students can engage at a deeper level inside the classroom (Strayer, 2012). This is called as flipped (also inverted) learning. However a central premise of flipped learning is that students will engage with this designated material prior to attending class allowing the face to face time to be used constructively, for example, to discuss how theory relates to real-life practice. This requires a level of organisation and motivation on behalf of the students. Under-prepared students will either be unable to engage in the face to face discussions in a meaningful way and may even cause distractions amongst their more prepared peers by asking for information and explanations that they should already have covered in preparatory work. Most of the papers about flipped learning have focussed on comparing educational performance in the flipped vs traditional environment and in the role of technology in moderating the engagement of the students (Bishop & Verleger, 2013). There has been limited data presented on whether students do engage and if there is a relationship between participation in the pre-work activities and performance in the unit.

Literature Review

The Australian tertiary education environment is experiencing a period of rapid change driven by political pressure to increase the proportion of the population enrolled in tertiary education (Bradley, Noonan, Nugent, & Scales, 2008; Dawkins, 1988; Gillard, 2008; Government, 2008), financial pressures resulting in a contraction of academic resources, and competition from other countries for international student income. This has resulted in a significant increase in student numbers and an increase in students who may be less prepared for the university experience than their peers in the past. Alarm bells rung over a shortfall of engineers by professional bodies has also contributed to pressure on universities to increase the size of engineering student cohorts (Australia, 2012).

Graduates are expected to develop generic and discipline specific competences through their university experiences. Although the language of generic competences varies by institution and discipline (Chapman & O'Neill, 2010), these competences can be broadly grouped into three 'types'. These are a) acting autonomously and reflectively, b) using tools strategically, and c) interacting in socially heterogeneous groups (Rychen & Salganik, 2003). Current developments in engineering education in Australia are aligned with the following six competency deficiencies – practical engineering, engineering business competencies, communication skills, self-management, and appropriate attitude, problem solving and teamwork (Male, Bush, & Chapman, 2009). Since 1999 the last four have been stipulated for program accreditation and it is necessary for academics to consider how these competencies are developed in each of their units (Male, Bush, & Chapman, 2010). While traditional engineering education has focussed on technical elements there are ongoing challenges with how to develop practical engineering and ‘engineering business’ competences in today’s student cohorts. The increase in student numbers has reduced the opportunity for each student to develop practical skills in laboratories as laboratory space, time and supervision expertise has decreased. Compounding this, the increase in student numbers has not been matched by an increase in industry-based vacation work opportunities so it is increasingly difficult for all students to get the work experience necessary to appreciate why practical and business skills are so important. Finally few of today’s academics have worked as engineers industry or dealt with the complexities of risk, cost, safety and performance in a commercial context makes teaching these skills a challenge.

As part of a strategy to develop ‘engineering business’ competences new units are being developed. These units, such as the one on risk, reliability and safety that is described in this paper, teach the students to deal with complex situations in which there is no one right answer. This is often a conceptually difficult step for undergraduate engineers who are used to deterministic situations and problems with well-defined boundaries, inputs and outputs. Real world problems have multiple stakeholders with diverse opinions, particularly of risk. Getting students to understand that there is a more diverse range of views and solutions in the classroom, let alone in the wider community is a desired stepping stone in developing business engineering skills.

One of the many challenges facing the modern academic is that students now expect to be entertained as part of being educated. The days of the untouchable "sage on the stage" are numbered (King, 1993). Academics who fail to engage with students in lectures are punished with poor student ratings and students turn to watching their lectures on recordings rather than attend the live event. There is competition for student's time and attention as many of them need to work part-time to pay for their university fees. This reduction in the time available for study causes the students to be strategic in what they engage in. They seek flexibility in order to match work and study. They also tend to focus on what they anticipate will be assessed rather than a holistic engagement with the core concepts of the course.

On a more positive note, technology is enabling greater flexibility in who has access to tertiary education, new teaching approaches and the associated data is allowing for greater scrutiny of both academic and student performance (Daniel, 1988). Although forms of remote delivery have been around for decades (Potashnik & Capper, 1998), it has tended to be offered by specialist providers such as Open University in the UK and by Australian universities focussing on regional and rural student bodies or specialist professional courses. It has only been relatively recently that the traditional sandstone universities have upgraded their learning management systems so that those academics wishing to use adopt more technologically-reliant delivery approaches can do so.

Flipped learning developed as a model for a more student-centric approach. It focuses on using the face to face class time for active learning and to promote student learning associated with the upper regions of Bloom's taxonomy (Lage & Platt, 2000). In order to achieve this, content delivery is "flipped" in that it is accessed by the students prior to the class in the form of readings, pre-recorded lectures and videos. Flipped learning consists of many elements of what is broadly understood to be good practice in education such as active learning, pre-class reading and quizzes, and flexible delivery. What makes it different from what has been done previously is the timing of these elements and the explicit focus on active learning in the face to face classroom time. Although there has been significant research on these elements, quantitative and rigorous qualitative research on the Flipped Learning experience in tertiary education is still limited (Hamdan, McKnight, McKnight, & Arfstrom, 2013).

There have been a number of recent papers looking at the student experience and describing the mechanics and effectiveness of flipped earning (Bates & Galloway, 2012; Bergmann & Sams, 2012; Marcey & Brint, 2012; Strayer, 2012; Warter-Perez & Dong, 2012; Zappe, Leicht, Messner, Litzinger, & Lee, 2009). Much of the initial research work on flipped learning in the tertiary sector has focussed on comparing the student educational outcomes and experience with the flipped vs. the traditional model (Bates & Galloway, 2012; Hamdan et al., 2013; Marcey & Brint, 2012; Thomas & Philpot, 2012). There are a growing number of examples of flipped learning in the science and engineering undergraduate curriculum (Dollar & Steif, 2009; Talbert, 2012; Thomas & Philpot, 2012).

Research has shown that by encouraging students to engage with pre-work material in the form of recordings, readings and quizzes before class a number of learning-related activities are stimulated. For example students engage in pre-learning. Research has shown that prior exposure to facts "prime" memory making it easier for subsequent recall and use of that information (Ratcliff & McKoon, 1988). When this pre-work is combined with assessment in the form of reflective writing and quizzes, the students can test their understanding of the pre-work and the academic can see, ahead of the class, which concepts are challenging for the cohort. This prior knowledge of the academic about the class supports adaptability in approach. This is another key tenet of flipped learning, in which the academic can adapt the class activities to address the concepts the students are finding intractable. The opportunity to read or watch material at their own pace and potentially many times is also believed to assist those who may be struggling technically or for whom English is a second language (Hamdan et al., 2013). The latter is particularly relevant for engineering cohorts which often have a significant proportion of international students.

Having delivered technical concepts prior to the class, class time can be dedicated to active learning activities which include opportunities to apply what they learn prior to the class, work with other students and getting immediate feedback from the academic. Carefully selected in-class interactional elements (peer-peer and student-academic) have been shown to increase student mastery of conceptual reasoning and problem solving (Crouch & Mazur, 2001). However the ability to have these informed interactional elements may be influenced by whether the students have engaged in the pre-work in the manner envisioned by the academic. The class experience is also highly dependent on the ability of the academic to make the mental shift required to accept and embrace an unstructured lecture experience in which the lecturer is no longer in complete control of discussions (Bates & Galloway, 2012).

Two studies examine participation in a flipped environment for engineering-related studies. One on the teaching of statics using data retrieved from the Learning Management System showed that 70% of students (n=63) completed graded online exercises and that average attendance per lecture was very high (83%) (Papadopoulos & Roman, 2010). A survey from the same study suggests that students appear to spend more time on the flipped class work and with more regularity than other non-flipped classes. A separate study for an introductory physics class show participation rates with quizzes of 91% (n-199) with an average score of 79%. Participation was measured using clicker question episodes and reported as being good although no data provided (Bates & Galloway, 2012).

This investigation involves a study of the relationship between participation in flipped classroom activities and performance in the unit. Guided by the research question “How does participation in flipped classroom activities relate to performance for engineers in a senior level class on risk reliability and safety?” The study investigate what activities they participated in and when during the 13 week class and if there is a relationship between participation and performance as determined by specific summative assessment relating to the unit. In addition the relationship between participation and performance of different groups, such as international and domestic students, and male and female engineers is also examined.

The paper is organised as follows. The first section describes the educational context in which the study was conducted including a description of the factors shaping the engineering program and details of the specific unit and the student cohort. The second section describes how this observational study was conducted with the results in the following section. The final section provides a discussion of the results of participation and performance and also reflects on the appropriateness of the flipped learning approach in building business engineering skills and engaging the students.

Educational Context

The engineering program at the University of Western Australia is in transition from the older style 4 year Bachelor of Engineering undergraduate program to a 3 year undergraduate generalist program with an Engineering Major plus 2 year Master of Professional Engineering (MPE) program. The structural change to a 3:2 Bachelors: Master program was made to align the Universities to the Bologna Process and the 2011 Australian Quality Framework (AQFC, 2013). Students entering the MPE can come from a variety of Bachelor backgrounds including Science, Business and Design. They may have done as few as 8 foundation engineering units (out of a Bachelor program of 24 units) but they have had exposure of a broad range of other subjects by the time they complete. The subsequent completion of the full time MPE program produces "T-shaped" engineering students who should have gained a broad general education including exposure to a range of non-engineering subjects and people followed by specific technical training. It is also attracting students who might otherwise not have elected to enter engineering as school levers and a significant number of international students.

Each unit in the new Master course structure has to map class activities and assessment tasks, level of development at the end of the unit, and indicators of attainment for three competency areas from the Engineers Australia Stage 1 competences. These areas are a) Knowledge and Skill Base, b) Engineering Application Ability and c) Professional and Personal Attributes. Many of the non-technical elements in these competences cannot be taught in a lecture format, they have to be developed by the student through practice and experience. The requirement to both develop and assess these competences is encouraging academics to explore new ways both in and out of the face to face classroom environment.

In 2013 a new unit on Risk Reliability and Safety was taught to (the old) 4th year undergraduate and new 1st year Master students. This unit develops students' technical and statistical skills in risk and reliability and also covers the social and organisational contexts which are so important in ensuring that products and services are designed, constructed and operated safely and reliably. The unit is taught to all engineering disciplines in one class to reinforce the need for cross-discipline collaboration and accommodation of diverse groups in risk and safety management.

There are two parts to the unit. The engineering content focusses on the theory of risk, reliability and safety and its application to real engineering problems. The statistical section covers essential statistical and probability material to support the use of these quantitative tools in risk and reliability. These concepts include probability distributions, sampling distributions, inference techniques including confidence intervals and hypothesis testing, regression analysis, and tools for reliability and life testing. The subject matter by its nature is non-deterministic, application of the concepts require interpretation, decisions are seldom clearly identified and often involve trade-offs. Given this context, a decision was made early in the development phase to teach this unit differently from traditional lectures. The aim being to give the students as much opportunity as possible to interact with experienced engineers, discuss issues, identify grey-areas, and practice decision making in an as near to real world environment using actual industry case studies. Risk and Safety decisions while grounded in engineering ideas have to be executed in a way that is acceptable to organisations and society (Beeman & Baillie, 2007).

In order to get to a point where students can hold an intelligent discussion about complex cases in risk, reliability and safety, they need to have an understanding of terms, concepts and tools in the area. There is a lot of theory in these three topic areas and if lecture time was dedicated to the delivery of material there would have been limited time in class for discussions. Traditionally these discussions have been done in tutorial classes but an absence of tutors with the necessary practical experience in risk, reliability and safety meant that this was not an option. The decision to use flipped learning was motivated by the desire to spend face to face time in class in peer-peer discussion and activities coordinated by academics with industry experience. It recognised that much of the theory could be delivered in pre-recorded lectures, videos and directed readings. Once they have engaged with the theory, the challenge is to develop an understanding of how they would apply the theory to real world situations. Some of the subject matter, for example safety tolerance and safety behaviour is very personal. Individuals will have different responses to the same situation. Getting students to both understand and reflect on their attitudes and values with respect to safety requires a more student-centred approach to learning. The flipped learning model accommodates this by providing opportunities for students to articulate their views to others within group discussions and then hear about others views in subsequent plenary sessions. Of course, having these discussions requires that students attend the lectures rather than watch recordings after as an increasing number are doing. The flipped learning model with its emphasis on flexibility in when students engage with the content and then a limited but intense and interactive face to face workshop may provide a greater incentive to attend.

Development of the Unit Structure

There are five assessable learning outcomes for the unit. These are that the students are able to (1) use appropriate tools to quantify risk and uncertainty; (2) select appropriate risk identification approaches; (3) use specific risk evaluation tools and models; (4) identify risk and safety controls; and (5) calculate standard reliability metrics.

The unit is divided into twelve teaching weeks. Each week covers a different engineering topic area in risk reliability and safety. Statistical and probability concepts required for each engineering topic are covered in weeks prior to that topic. In the middle of the term the engineering cohort is broken into disciplines for two weeks of discipline-specific topics in mechanical/ electrical, chemical, mining and civil engineering. The material covered in these discipline specific topics is not discussed further in this paper which concentrates on core topics taught to the entire cohort.

Prior to the start of each week the students are provided with a list of instructions for the material they must cover ahead of the engineering face to face workshop held weekly on Friday afternoon. The pre-work involves watch ~ 5 recordings, each about 10 minutes long, which covered the core content for the week. These recordings were usually a mix of PowerPoint presentations and videos, particularly about major engineering failures. In addition they are sometimes asked to look at specific internet sites to find information on engineering standards and regulations, or to read articles. To encourage students to engage in this pre-work the students take an on-line multiple choice quiz. The questions are based on the content of the pre-work. Weekly quizzes (N=8) contains ten questions. Their overall score in the engineering quiz questions is worth 10% of the final grade. There are 2-3 questions on each section of the pre-work. The students have unlimited attempts at the quiz but for each attempt the questions change. On average the students have 7 attempts. Students know their score after each quiz attempt. At the end of each week the results of both the engineering and statistics quizzes are available to the students.

The face to face workshop is usually based around one or two case studies. It is structured so that the students are introduced to a problem/ situation and presented with a set of questions. These questions are discussed in small groups of 3-4. The facilitator then identifies groups to share their responses with the class. This provides opportunity for the students to practice discussing in their groups how they would address the problem and by listening to the responses the workshop facilitator can correct misconceptions and explore ambiguities. Six of the nine workshops covered in this study were delivered by the unit coordinator and the remaining three by three other academics from chemical, environmental and software engineering respectively. Attendance at the workshops is recorded but there is no grade associated with attending.

The statistics material is also assessed weekly (N=9) using an online multiple choice quiz of 10 questions. The questions involve calculations and while the students get the same question the numbers in the problem are randomly generated to prevent direct copying. Unlike the engineering quiz questions which are aimed at encouraging engagement with the material, the statistics questions are summative and allow the students to see if they have grasped a particular topic or not. They have two attempts at each question and these quiz questions contribute to 15% of the final grade.

There are two summative tests, a mid-term (1hr 40 min) in week 8 and a final exam (3 hrs) after the end of semester. Both exams are multiple-choice and prepared by the same two staff, an engineer and a statistician who prepare the weekly quizzes. The mid-term is worth 20% of the unit grade, and the final exam is worth 45%. The split between engineering and statistics questions is approximately 50%. The engineering section of the final exam contained sets of questions on three case studies, one from Week 2, Week 4 and Week 5, as well as individual questions from other sections of the unit.

Quiz performance is assessed by determining the proportion of correct answers out of the total number of questions across the unit. Engineering quiz participation is assessed by determining the number of weekly quizzes attempted and the number of attempts made until final submission of the quiz.

In summary there are 4 elements of participation and 4 elements of performance assessment for the engineering content as shown in left column in Table 1. Data on performance and some participation elements (marked with *) is available through the Learning Management System or was recorded manually (marked with **).

Educational Context

This study takes a positivist approach to the phenomena of participation and performance. It is based on the assumption that participation can be measured by observing certain activities of the students and results in exams are a measure of performance. It was conducted by means of data collection and quantitative analysis with students in the researcher's own classroom.

Table 1. Summary of participation and performance assessment elements for the Risk Reliability and Safety unit

Measure	Engineering	Statistics
Participation (hours/ week)	Interactive Workshop (1.75 hours**	Lecture (0.75 hour)
	Pre-work: watching recordings and directed reading (~2 hours)*	Tutorial (0.75 hour)
	On line quiz on pre-work (~1 hour)*	On line quiz (~ 2 hours)*
	Discussion board (adding posts and reading existing posts)*	Discussion board (adding posts and reading existing posts)*
Performance assessment	Final exam (45%)	
	Mid-term test (20%)	
	On line quiz (10%)	On line quiz (15%)
	Assignment (10%)	

The approach assumes that activities recorded by noting the opening and closing of files (Papadopoulos & Roman, 2010; Thomas & Philpot, 2012) or making entries in the LMS via quizzes (Bates & Galloway, 2012; Kibble, 2007) and discussion boards are indicative of participation. The advantage of using the LMS is that the digital data is objective and not subject to recall bias or perceptions of the students when participation is determined through surveys.

Steps were taken in the unit design stage to ensure that participation data could be collected by the LMS. Data is collected on 1) attendance at the workshop, 2) what pre-reading was opened, 3) if quizzes were attempted and how often , 4) looking at and 5) posting on discussion boards. Two measures of performance are analysed, the first is the total score for the unit. This final unit score includes all the engineering and statistics assessment elements shown in Table 1 and is used to place the students into different quartile groups. The participation and performance in different activities in the unit are considered for each quartile to determine if there are significant differences between the following groups. In addition to quartile performance the following group differences are also examined.

- International and domestic students
- Master (MPE) and undergrad students
- Female and Male students

In the quartile analysis there were 388 students. 20 students were omitted for reasons outlined in the following section.

The second measure of performance is the score obtained by the students in the summative assessment for the engineering section in the final exam. The final exam is worth 45% of the course. The relationship between the performance elements in the engineering section of the course and students' performance in the engineering questions in the final exam are modelled using multiple linear regression. In conducting this modelling it is necessary to account for the learning ability and motivation of the students. This was done by including their Course Weighted Average in the analysis. The CWA score can be regarded as proxy of competence with respect to factors likely to assist performance at Universities such as intellectual capacity, time management and motivation. There are 33 students who do not have a prior CWA; 31 are international master and 2 domestic master students. In order to account for the potential influence of CWA score on performance in predicting the score in the Engineering questions of the final exam a new data set without the 33 zero CWA scores was produced. This resulted in a revised data set for the regression analysis with n=355.

The study was conducted in 2013. There were 407 students enrolled in the unit. Ethics approval was obtained for the study.

Results

Participants

The student group contains both domestic and international students as shown in Table 2. Many of the international students come from South-East Asia and China and will have been in Australia for less than a year. The small group of cross-institutional students are on exchange from northern Europe. Out of the student group of 407 there is a small number of women 64 (15.7%).

Table 2. Risk, Reliability and Safety Student cohort details

Degree	Domestic	International	Total
Bachelors	251	76	327
Masters	14	61	75
Cross institutional	0	5	5
Female	43	25	68
Male	222	117	339
Total	265	142	407

Students from the initial groups were excluded from the analysis for the following reasons: (i) Request to be removed from the study as part of Ethics process (n=1); (ii) Cross-institutional (n=5); (iii) Part-time students (n=2); (iv) Completed some other assignments but did not take the mid-term test (n=4); (v) Failed to complete >10% of the unit (n=4); (vi) Deferred exam, so final grades are not available at the time of writing the paper (n=5).

This results in a population of 388 for analysis for whom a complete data set is available. Of these coming into the unit, 16 students had High Distinction averages (>80), 106 Distinction (70-80), 145 Credit (60-70), 81 Pass (50-60) and 8 Fail (<50), the 32 Masters students had not accumulated sufficient units to have a unit average.

Data analysis

All statistical analysis was completed using R with data manipulation done in Excel. A 5% significance level is used for all statistical tests. Table 3 shows descriptive statistics for the performance and participation of each quartile. There are 97 students in each quartile. A summary of participation and performance by different groups, domestic and international students, female and male students and bachelor and master students is shown in Table 4.

Performance

The data in Table 3 shows a consistent pattern between score in each individual element of assessment (engineering quizzes, statistics quizzes, mid-term test and final exam) and place in quartile group based on final unit score. The mean of the final score is 65.1%, median 65.5% and standard deviation 9.71%. There is a positive correlation between the grade point average (GPA) of students prior to the unit and the final score in the unit (n=356). There are 32 International students who did not have sufficient units completed at this University to have accumulated a GPA.

Participation

In the flipped learning part of the program there is a weekly engineering workshop. Students are expected to complete pre-reading prior to the workshop. Attendance data was collected for workshops in weeks 1, 2, 3, 4, 5 and 10 and 11. Over the first 5 weeks of semester attendance at the workshop was 88%. By in weeks 10 and 11 it had dropped to 50%. This drop is probably explained by the large proportion of the class that had an honours dissertation due at the end of week 11. Almost 70% of students attended 5 or more of these 7 workshops with 25% attending all 7. There were 6 students who did not sign any attendance sheet for any workshop. The quartile data in Table 3 shows that there is no significant difference in attendance at the workshop and the final grade quartile. Approximately 70% in each quartile regularly attended the workshop.

Between four and seven pre-work activities are assigned each week, each lasting on average 10 minutes. This pre-work that the students can access on any digital platform and includes pre-recorded lectures, videos and readings. The numbers for engagement in the pre-work are generated by counting which activities are opened for each student and taking the average across the cohort. This pre-work engagement decreased through the term from an average of around 50% in the first half of term to 30% in the 2nd half. There are significant differences in participation in the pre-work activities by quartile. The students in the 4th (top) quartile open almost twice as many pre-work activities than those in the 1st (lowest) quartile. There are 66 students (17%) who opened less than 5 or the 46 required pre-reading activities. Only 20% of the students opened 76% or more of the pre-work activities.

Table 3. Performance in the Unit by Final Score Quartile (n=388)

Performance Statistics				
Measure	Quartile 1 (30.3-59.2*)	Quartile 2 (59.3-65.5*)	Quartile 3 (65.6-71.9*)	Quartile 4 (72.0-90.2*)
Unit Weighted Average Prior to this Unit	52.47(19.68)	58.73(17.54)	60.37(21.71)	70.56(16.17)
Quiz Score – Engineering (/10)	7.68(1.99)_	9.26(1.20)	9.38(0.92)	9.68(0.53)
Quiz Score – Statistics (/15)	7.50(3.78)	12.22(2.09)	13.01(1.53)	13.35 (1.32)
Mid-Term Exam Total (/20)	10.48(1.91) 52.4%	11.43(1.57) 57.2%	12.48 (1.52) 62.4%	14.11(1.46) 70.6%
Final Exam – Total	44.3%(7.95)	49.5%(7.48)	57.9%(5.95)	71.3%(7.50)
Final Exam – Engineering section	41.2%(10.6)	44.1%(9.6)	50.9%(10.8)	65.7%11.6
Final Exam – Statistics section	47.8%(11.4)	55.5%(9.5)	65.6%(10.3)	77.5%(9.2)
Overall Unit Score	52.5%(6.2)	62.5%(1.8)	68.4%(1.8)	76.8%(4.4)
Participation Statistics				
Measure	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Average % workshops attended	69%	71%	72%	71%
Average % pre-work opened at least once	35%	41%	46%	60%
# Engineering quizzes opened (/8)	6.74	7.66	7.64	7.88
Average # attempts at each engineering quiz	4.67	4.75	4.40	4.06
# of students posting on discussion boards	17	23	34	37
Average # of posts added per student	0.51	0.92	2.06	3.20
Average # posts viewed per student – Total	103.95	167.42	193.05	241.84
Average # posts viewed per student – Engineering discussion boards	27.62	38.30	48.67	65.76
Average # posts viewed per student – Statistics discussion boards	76.34	129.12	144.38	176.08

* Final unit score range for quartile

Table 4. Comparison of participation and performance by different groupings of the student body

Measure	Domestic	International	Female	Male	Bachelor	Master
# Students	255	133	62	326	316	72
% Total	66%	34%	16%	84%	81%	19%
% in 4th (top) quartile	82%	18%	11%	89%	86%	14%
% in 3rd/ 2nd/1st quartiles (Q3-Q1)	Q3 - 61% Q2 - 55% Q1 - 65%	Q3 - 39% Q2 - 45% Q1 - 35%	Q3 - 16% Q2 - 22% Q1 - 14%	Q3 - 84% Q2 - 78% Q1 - 86%	Q3 - 76% Q2 - 80% Q1 - 77%	Q3 - 22% Q2 - 18% Q1 - 21%
Engineering Quiz score	89.5%	90.9%	90.86%	89.83%	89.74%	91.12%
Statistics Quiz score	76.3%	77.7%	80.20%	76.13%	75.67%	81.53%
Final exam score – Total	56.34%	54.58%	53.66%	56.13%	56.41%	52.78%
Final exam score – Engineering section	51.38%	48.69%	47.27%	51.07%	51.37%	46.45%
Final exam score – Statistics section	61.87%	61.16%	60.79%	61.78%	62.04%	59.82%
Overall unit score	65.29%	64.68%	64.77%	65.14%	65.25%	64.34%
% workshops attended	70.43%	71.56%	70.71%	70.86%	70.43%	72.57%
% Required pre-work opened at least one	51%	35%	47%	44%	45%	40%
Average # attempts at each engineering quiz	4.39	4.62	4.29	4.51	4.29	4.51
Number (%) of individual students posting on discussion boards	77 (30%)	34 (26%)	22 (35%)	89 (27%)	94 (30%)	17 (24%)
Total # posts made by students	476	174	97	550	578	72
Average # posts added per student	1.87	1.31	1.56	1.69	1.83	1.00
Average # posts viewed per student - Engineering discussion boards	50	35	55	43	45	44
Average # posts viewed per student - Statistics discussion boards	141	112	170	124	132	128

There are two sets of quizzes in this unit. The nine weekly statistics quizzes were completed by 100% of the students; only two attempts are allowed for each statistics quiz and all students made two attempts. Fewer of the eight engineering quizzes were attempted (average=6.74) by the 1st quartile than the 4th quartile (average=7.88). Unlimited attempts are allowed for the engineering quizzes. The lowest quartile students had more attempts on average at the quizzes than the top quartile students.

There is a difference in participation in the discussion boards between the quartile groups. Board participation is judged by a) the addition of posts either by posting a question or by responding to a question, and b) viewing posts. In total there were 650 posts to the engineering and statistics weekly discussion boards during the unit. These were contributed by 111 students (28.6%) with 64% of these students being in the top two quartiles. The average number of posts added per student in the quartile is 6 times higher for students in the top compared to the bottom quartile. In the top quartile there were 311 posts added with 184 (59%) added by just 5 students. In the 2nd top quartile 88 of the 200 posts (44%) were added by 3 students.

Comparison of Female and Male students

In the unit 16% of the students are female and 84% are male. A summary of the performance and participation of the female and male student cohorts is shown in Table 4. Comparing the results in the unit score, final exam, and quizzes there is no significant difference in performance between female and male students. The unit performance by quartile shows only slight differences between female and male students relative to their population. Females were less dominant in the top and bottom quartiles with performance clustering in the 2nd and 3rd quartiles. 89% of the top quartile performers are male compared to a population in the unit of 84%.

There are no significant differences in participation for attending workshops, opening pre-work and attempts at quizzes. Females had higher levels of engagement with viewing the discussion boards than their male colleagues but the male cohort added more posts.

Comparison of Domestic and International students

In the unit 66% of the students are domestic and 34% international students. Of the 133 international students 59 (44%) are Masters and the remainder are Bachelor degree students. A summary of the performance and participation of the domestic and international student cohorts is shown in Table 4.

Comparing the results in the unit score, final exam, and quizzes there is no significant difference in performance between domestic and international students. Looking at quartiles based on unit performance, the 4th (top) quartile for performance in the unit is dominated by domestic students (82%), the 1st and 3rd quartiles broadly split along population lines with 65% and 61% respectively, while in the International students have slightly higher numbers in the 2nd quartile compared to their population average.

There are no significant differences in participation for attending workshops and attempts at quizzes however domestic students have much higher levels of engagement with the discussion boards and pre-work than their international colleagues. The domestic students had significantly more views of the discussion boards, an average of 191 views per domestic student compared to 147 views per international student. 30% of domestic students made at least one post compared to 26% of international students. On average domestic students only looked at 50% of the pre-work; the number was even lower for international students at 35%.

Comparison of Bachelor and Master students

In the unit 81% of the students are bachelor and 19% master students. A summary of the performance and participation of the cohorts is shown in Table 4.

Comparing the results in the unit score there is no significant difference in performance between Bachelor and Master students. The Masters student showed significantly better performance in the Statistics quizzes, 81.5% compared to 75.7% for Bachelor students, but both groups had similar results on the Statistics section of the final exam with the Bachelor students over performing the Masters students slightly. The Masters students as a group did poorly on the engineering section of the final exam with an average of 46.5% compared to 51.4% for Bachelor students.

There are no significant differences in participation for attending workshops and attempts at quizzes. Masters students were less likely to open pre-work as were International students with many common elements in both groups. Masters students were the least likely group to make a post on the Discussion Board (24%) but had similar viewing rates as their Bachelor colleagues.

Student educational experience

Units are assessed across the University using the Students' Unit Reflective Feedback. This is a survey sent electronically to all students asking six questions. Response rate for the survey was 47.4%. The results for each question were equal to or above the School and Faculty average. It is unusual for new classes, especially new large classes and those using new approaches, to score as well as established units.

A second electronic survey, the Student Perception of Teaching Survey (SPOT), also anonymous was conducted by the academic. This had a response rate of 39.4%. When asked in this survey about the best aspects of teaching in this class the key themes were

- Interactive workshops and being encouraged to participate in class
- The weekly engineering quizzes kept students up to date with the content
- Being able to complete the weekly work in small chunks at their own pace,
- Having done the pre-work made the lectures makes the workshops more engaging

The SPOT survey also provided some feedback on what students felt needed to change to improve their learning. The main themes were that too much work was expected, workshop classes should be smaller instead of 200+ and not be held on Friday afternoons, and to reduce the number of discussion boards.

Discussion Items

Participation

This study delivered some surprises in terms of participation in a flipped learning environment, one positive, one negative. There were, on average, high levels of attendance at the weekly engineering workshop which ran late on Friday afternoon for 2 hours. On average 70% of students attended. No published figures were available for comparison of attendance in flipped vs traditional class but anecdotal evidence from colleagues is that attendance at lectures and workshops is often as low as 20% as they are all recorded. Many students now choose to watch lectures online at their own convenience. A plausible explanation for the strong attendance, supported by comments in the SPOT survey, is the emphasis in the workshop on student- led activities and participation. These high levels of attendance at the face-to-face session in a flipped learning environment are in line with other studies (Papadopoulos & Roman, 2010).

There is a strong relationship between performance by quartile group with participation in the flipped learning activities as shown in Table 3. For every participation element, the level of participation rises in line with quartile performance measure. Students in the lowest quartile for performance have the lowest levels of participation in all of the elements. The challenge in interpreting this is in separating out the intelligence, time-management skills and motivation of the students from the benefits obtained from participation. It is known that, in general, students who take advantage of every learning opportunity are likely to have better performance outcomes (Heffler, 2001). In other words, students that do well at university in general, will do well in this flipped learning environment because they have acquired and routinely apply appropriate skills. This idea is supported by examining the relationship in Table 5 between the Course Weighted Average (CWA) of the students at the start of the unit and their performance in the unit. The CWA score can be regarded as proxy of competence with respect to factors likely to assist performance at Universities such as intellectual capacity, time management and motivation.

The results of the regression analysis are shown in Table 5. The regression results indicate that CWA is highly significant in the prediction of exam performance ($p<0.0001$) in this class. This is in line with the findings of (insert ref to Thomas) who identified a similar relationship between CWA and exam scores in his flipped classroom.

Table 5: Linear regression on the influence of participation elements on performance in the engineering section of the exam; significant elements in the relationship are indicated by low p-values.

Variable	Coefficient	Standard Error	*t*-statistic	*p*-value
Constant	0.0567	0.0659	0.986	0.3905
Course Weighted Average (CWA)	0.0064	0.0008	7.907	<0.0001 ***
Gender (Male)	0.0506	0.0166	3.038	0.0026 **
International or Domestic student (International)	-0.0753	0.0151	-4.964	<0.0001 ***
Degree (Master)	-0.0099	0.0213	-0.467	0.6406
No. of views of Engineering discussion boards	0.0002	0.0001	1.463	0.1476
Workshops attended	-0.0029	0.0032	-0.910	0.3636
Eng. Quiz attempts	-0.0021	0.0064	-0.339	0.7348
Eng. Prework material opened	0.0016	0.0005	3.134	0.0019 **

Of the four elements of participation, only the element involving reading the prework was significant in the regression analysis ($p=0.0019$). The other three elements are not significant using this analysis approach for the following reasons. Attendance at class, especially as the mean attendance is high anyway is unlikely to be a distinguishing feature in separating performance and it is possible for the students to attend but not participate. Counting the number of attempts at engineering quizzes is also not likely to be a good predictor of performance as the better prepared and intelligent students are likely to have less attempts than those who do the quiz multiple times with a trial and error approach, hence the relationship has a negative coefficient in the linear regression. Previous studies of the effectiveness of online quiz participation and scores on performance in summative assessment have postulated that when quiz use correlates with summative performance that this probably reflects the expected relationship in which more expert learners perform better (Kibble, 2007). It is not possible to remove the effects captured by the CWA in the quartile analysis hence the strong relationship displayed in Table 3 using the quartile-based approach between participation and performance.

Between group analyses

Using the quartile analysis there is no significant difference in performance or participation between female and male students. The linear regression indicates that males are likely to outperform females ($p=0.0026$) in the engineering section of the final exam but this relationship may be skewed by the concentration of the much smaller female population (16%) whose performance is clustered in the 2nd and 3rd quartiles.

A comparison of Bachelor and Master students is complicated by the unequal distribution of International students. International students represent 81% of the Master cohort and only 23% of the Bachelor cohort. The linear regression indicates that International and Master students are less likely do well than their domestic peers ($p<0.0001$) in the engineering exam. There are no significant differences from the quartile analysis in terms of participation of the two groups however the results indicate that Masters students were less likely to open the pre-work and to engage in the discussion boards. This is likely to be connected with challenges including lack of confidence with English.

Role of the discussion boards

There was a high level of participation in discussion boards in this unit. There were 54,505 views of the statistics weekly discussion boards (n=11) and 18,517 views of the engineering weekly boards (n=9). The engineering total excludes weeks 6 and 7 which were focussed on discipline specific subject areas. The weekly discussion boards were viewed at least once by all (407) except two students. Students in the top (4th quartile) viewed both sets of discussion boards more than the 3rd quartile who viewed more than the 2nd quartile who viewed more than the 1st quartile. Students in the 4th quartile viewed discussion boards 2.4x more than students in the 1st quartile.

An example of a typical discussion board thread is given below. This illustrates how discussion boards can give insight into what students do and don’t understand, provide opportunity for students that do understand (Student C) to help their peers (in this case on a key concept to do with repairable vs non-repairable systems), and also provides a record that other students can access.

> Student A: It made sense to me that availability would be defined as MTTF/(MTTF+MTTR), and this is also given in the formula sheet. So I'm wondering, why is this incorrect in the quiz?
> Acad: Think about the distinction we are trying to make between MTTF and MTBF. What assumptions are behind the choice?
> Student B: Is availability not equal to the [available time to do work / (the available time to do work + the time unavailable to do work)]? Shouldn't Availability = MTTF/MTBF, which is also MTTF/(MTTF+MTTR)?
> Student C: The definition of availability will change depending on whether the item is repairable or non-repairable. I hope this helps.
> Student A: Yes, but I would argue either MTTF or MTBF are correct, depending on the situation, i.e. whether it is repairable or not.
> Acad: Well done to all who have participated in this discussion. There are a number of lessons here which your discussion has brought to light.
> 1. There is a difference between MTTF and MTBF. It relates to non-repairable and repairable systems as Student C pointed out.
> 2. In many cases there is an assumption with non-repairable systems that MTTF>>>>MTTR. This is the assumption I used in deciding the answer.
> 3. However, if MTTF is not much greater than MTTR then either definition would work

Applicability of the flipped learning approach for generic competence development

Core generic competences for University Graduates include a) acting autonomously and reflectively, b) using tools strategically, and c) interacting in socially heterogeneous groups (Rychen & Salganik, 2003). The flipped learning model as described in this paper helps to develop a) and c). It encourages student to take responsibility for the pre-work and provides opportunity for them to interact with others in class. Some students obviously struggle with one or both of these but others value them as illustrated by quotes from the SPOT surveys.

> "Was encouraged to participate in class and the engineering quizzes stimulated me to keep up with the content of the unit"
>
> "Class participation helps me to gain communication skill with classmates."
>
> "I liked the interactive workshops where ideas are shared openly and students are encouraged to engage with the people around them."

Compared to one comment "Remove any student collaborative activities in class- it's just time consuming, and we students hate to collaborate in class."

Applicability of the flipped learning approach for the subject material

The flipped learning approach has worked well for the subject material which has some foundational theory but the challenges in application can only really be revealed by engagement with examples and case studies. The model supports delivery of the sometimes dry theory in the recordings and pre-work material and allows the student to demonstrate they can apply the concepts in the workshops. Feedback on the SPOT surveys indicate that many students appreciated this.

> "Workshops on real cases helped in understanding the safety and reliability concepts better"
>
> "The ability to complete the weekly work in small chunks at your own pace in formats that varied from week to week (textbook readings, documentaries, recorded lectures, standards, case studies etc.) - this kept it fresh & interesting! rather than boring lecture after lecture."

"The content that is provided before the lectures makes the lectures much more engaging. The content gives you a background so that you can understand what is happening in the lecture."

Developing 'engineering business' skills

There are some slight but interesting differences between international and domestic students. International students outperform domestic students by a narrow margin on the weekly quizzes and do equally well in the statistics section of the final exam. However they underperform domestic students by 2.7% of the engineering questions of the final exam. The engineering exam questions were largely based on case studies and therefore require an understanding of context and some added complexity in interpretation. The challenges some of the international students have with English may be a factor. Only 35% of the pre-work was opened by the international students compared to 51% by domestic students and they made much less use of the discussion boards. Understanding this low participation is a subject for future research.

Workload considerations

One criticism of flipped learning has been the workload, particularly for the academics (Bates & Galloway, 2012). It requires time to develop and record the pre-work materials and to develop the weekly quizzes. However once made, these can be reused and easily updated. There was a reasonable amount of feedback in the SPOT results about the workload from the student perspective. Views were split with some feeling that there was too much to do each week and others more positive noting that the staged approach with regular assessment scaffolded their learning through the semester resulting in less stress for the exams at the end as indicated by the quote below.

"The interactive nature of the workshop were great to consolidate knowledge learned throughout the week. Online material was great as it allowed you to cover the material at your own pace and in your own time. The weekly assessments were great to force you to always be up to date with the content."

Implications for teaching

The results from this study will inform future developments of this unit as follows. The study itself will be shared with students in order to alert them to the importance of participation in the flipped learning classroom. More needs to be done to assist the large numbers of International students to engage with the pre-work, in the classroom and through the discussion boards. This is particularly important as the context of the subject matter (risk and safety) is not clear cut and understanding processes and how they are (and are not) applied requires discussion.

The study reported high levels of attendance at the face to face workshop (70%), this is in contrast to reports of falling levels of attendance in traditional lectures as students now often choose to watch post-lecture recordings. This suggests that the student centred activities in the flipped workshop are successful in attracting the students.

One surprise in the study was the relatively low level of effort put into the required pre-work with students in the highest performance quartile opening only 60% of pre-work, this number dropped to 35% for students in the lowest quartile. Obviously this relatively low level of effort put into the pre-work has implications for the quality of peer-peer discussions in the flipped learning workshop.

While this paper has shown what data collection and analysis is possible with modern Learning Management Systems, extracting the data and manipulating it to form the data sets for analysis was very laborious. The LMS used for this study did not appear to have considered the needs of academics interested in analysing participation data collected by the system. Data on each of the 80 activities had to be extracted separately, sorted, grouped using pivot tables and then stored. It is hoped that future developments in LMS will consider the needs of educators keen to use this data and improve their functionality to make data extraction easier.

Conclusions and future research work

This article examines the relationship between performance and participation in a flipped learning class. It looks are whether students look at the lecture material prior to class, how much effort is put into the pre-workshop quizzes and the relationship between participation in these pre-workshop activities and performance in the unit. The focus is on a large class of engineering students studying risk, reliability and safety, subjects that include both deterministic ideas as well as fuzzy and stochastic concepts with high levels of real world context. The study finds that when performance and participation are examined at a group level (by quartiles based on final grade) there is a strong relationship between participation elements and performance. Other less significant predictors are Domestic (as opposed to International) status, and students' approach to pre-work in preparation for the weekly workshop. These findings are significant as there is very little data on participation in flipped learning classrooms with most prior work using limited or self-report rather than multi-activity objective data collected using the Learning Management System.

This study raises some interesting questions about participation particularly how the students engage with the pre-work and the role of discussion boards in peer-peer learning. What proportion of students open the quiz questions and then go looking for the answers in the pre-work, if so, how does this influence their learning experience? Do other students who use the quiz as a way of self-assessing their understanding, having completed all the pre-work content, perform better than those focused only on the quiz marks? How can we encourage more of the latter behaviour? Why are international students less willing than their domestic colleagues to open and watch the pre-work recordings?

There was extensive use of discussion boards in this class. What are the factors that encourage students to post their own questions and answer others questions on these boards? Why is there such a difference in participation between international and domestic students in both posting and viewing discussion boards?

In addition further work to better understand how motivations of the students influences their views of, and engagement in, the flipped learning approach will be useful in developing strategies that assist students to make the most of this environment.

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