Flipping the Classroom in an Engineering Design Unit

Scott Wordley[a], Lim Jen Nee Jones[b], Matt Taylor[a] and Ashlee Pearson[a]
Department of Mechanical + Aerospace Engineering
Monash University Clayton Campus[a], Monash University Sunway Campus[b]
Corresponding Author Email: scott.wordley@monash.edu

CONTEXT

Flipped learning is the inversion of activities which traditionally take place in and outside of the classroom. Rather than attend a physical classroom to hear content delivered in a lecture, students review this material in a video or written format prior to in-class activities. Short online quizzes are commonly used to ensure basic comprehension of this pre-class material. Valuable face-to-face class time can then be utilised for more active learning, where students attempt problems with the assistance of their peers and the teaching staff. The switch to this teaching model in a second year engineering design unit was motivated by a desire to increase student learning, engagement and satisfaction.

PURPOSE

The objective of this research project is to assess student engagement with, and attitudes towards, the use of a flipped classroom teaching model and associated resources in an engineering design unit.

APPROACH

An existing unit, MEC2402: Design 1, was redeveloped for a flipped classroom delivery. This involved translating the pre-existing lecture content into a series of short narrated slide show videos which were hosted online for ease of student accessibility. Short online quizzes were developed to motivate utilisation of these videos and to test for basic comprehension of the material. The assessment breakdown was modified to provide a small amount of marks for successful completion of these quizzes. Lectures were rebranded as ‘workshops’, and problems previously used as tutorial and homework activities were incorporated into printed ‘worksheets’, which were attempted during the workshops with the assistance of peers and guidance from teaching staff. These worksheets were reviewed by demonstrators in the tutorial time and also attracted a small mark for completion. An anonymous online survey was used to gather feedback and assess student attitudes toward these new resources and activities. YouTube and Moodle metrics, as well as workshop attendance rates were used to evaluate student engagement. Comparisons between specific control exam questions for the previous unit offering and the first flipped offering were used to assess any changes in student learning outcomes.

RESULTS

The current study measured strong student support and satisfaction after implementing the flipped classroom model, with a 93% approval rate and 90% of respondents enthusiastic to see it applied in other units. Online engagement and student attendance both improved significantly compared to previous offerings of the unit, and were more consistent throughout the semester. Student learning outcomes were found to be as good, or slightly improved, based on a comparison of control exam questions before and after the change to a flipped classroom teaching model. Student evaluations of the overall unit quality also increased from 3.99 to 4.73 (out of five) following the switch.

CONCLUSIONS

A flipped classroom teaching model was successfully developed and implemented in a second year engineering design unit. These changes required a significant upfront investment in time and effort from the teaching staff but have resulted in improved student and teaching staff satisfaction with the unit.

KEYWORDS

Flipped Classroom, Flipped Learning, Active Learning.

Introduction

In its simplest form, “flipping the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa” (Lage et al., 2000). The flipped classroom aims to redistribute the activities that lead to learning more efficiently, by moving the more passive review of new content into students’ free time, and bringing more active learning into the class, where teaching staff and peers are present to support the process of learning through social constructivism (Vygotsky, 1978). Bishop and Verleger (2013) define the flipped classroom model as consisting of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom. Simply setting pre-class readings and engaging in some active learning in lectures is not sufficient to meet their definition.

Inside the flipped classroom, the focus is student-centric; it is less about “what the teacher does” and more about “what the student does” (Biggs, 1999). This model can be used to disrupt student preconceptions about what can be done in a lecture theatre by introducing active, peer-assisted, collaborative, cooperative and problem-based learning techniques (Felder and Brent, 2003)

Research on the effectiveness of active learning (Prince, 2004) and more specifically its application within a flipped classroom context (Bishop and Verleger, 2013) is slowly emerging and indicates significant student preference for the new mode and in some cases modest improvements in measured learning outcomes. A study at Pennsylvania State University (Zappe et al., 2009) showed that about 48% of the students preferred using class time for problem solving activities, with 36% having no preference. 75% also felt that their understanding of concepts was improved by spending the additional time in class on problems. Toto and Nguyen (2009) found that students preferred using class time for problem solving and hands-on activities while moving lecture material out of class time was beneficial. It was also found by Day and Foley (2006) that the average student in their flipped classroom offering scored significantly higher on all tests, projects and assignments than their counterparts who were provided with a more traditional lecture delivery method.

Context and Motivations

MEC2402: Design 1 was selected to trial the flipped classroom approach within the Faculty of Engineering at Monash University. This unit is core within the second year of Mechanical, Aerospace and Mechatronics Engineering degrees. It runs concurrently at the Clayton and Sunway campuses in Semester 1 of each year. Clayton enrolments commonly number around 250 students, whilst Sunway attracts around 100 students.

The learning outcomes for this unit include an introduction to the engineering design process, technical drawing and Computer Aided Design (CAD) tools (Wordley, 2014). The unit also features a major team-based, design and build project based on the annual Weir-Warman Competition provided by National Committee on Engineering Design (Wheeler and Smith, 2014)

The teamwork, hands-on and CAD components of this course are considered very important from an accreditation perspective. Engineers Australia defines Stage 1 competencies that higher education providers must satisfy so that their graduates can be accredited at a professional level (Engineers Australia, 2016). The introduction of the CAD component into this course in 2013 caused considerable pressure and potential content overload for students. A drop in student quantitative ratings of the overall unit quality (from 4.1 to 3.9) and written feedback indicated that significant changes were needed to improve the ratings, increase the efficiency of student learning, and maintain the required content. It was hoped that a shift to a flipped delivery mode would make better use of the two hours per week of lecture time, by engaging students with active learning and providing the ‘content delivery’ in a more granular and accessible short video format.

There were several aims of this research project. The first was to develop a new assessment model and the required teaching resources to support a flipped classroom approach. The second was to determine what effect assessed pre-class and in-class activities, had on student motivation and engagement with the provided study materials. The third was to increase student satisfaction with the unit and to gauge student response to the flipped classroom teaching model as a whole. The final aim was to try and measure any changes in students learning outcomes resulting from the shift to this new teaching mode.

Methodology

Teaching and Assessment Model

The distribution of assessments within the unit was given careful consideration. The flipped classroom typically requires the allocation of more marks for the completion of pre-class quizzes and in-class activities. The provision of marked online quizzes was intended to motivate students to review the study resources (videos and readings) in preparation for the workshops. Due to the large class size, workshops were held in traditional lecture theatres with a pitched floor. To motivate workshop attendance and engagement, students were provided with printed worksheets to complete. Separate tutorial times were provided to allow students to seek clarification and ask questions of the teaching staff and their peers. Once complete, the worksheets were reviewed by the tutors on the spot (rather than collected for later marking), and a unit specific, dated stamp was applied to denote correct completion. Students consequently received timely and detailed verbal feedback and correction of their work. To maximise the time available to demonstrators to provide this feedback, staff insisted that students retain all their completed and stamped worksheets until the end of semester, at which point they were counted and the total marks allocated only once. This negated the need for teaching staff to manually record the mark for each worksheet for each student during class time, which maximised the productivity of teaching staff. This model also spread the demonstrator review and feedback opportunities more evenly across the whole tutorial time, as the majority of students arrived with near complete answers or well-formed questions about the material. In the final assessment model, pre-workshop quizzes were allocated a total of 8% (~0.5% each) of the unit marks and worksheet completion 8% (~0.5% each). This was considered the minimum required to motivate students to complete this work.

Teaching Resource Development

Pre-class Videos

The Pre-Workshop videos were derived from the unit's existing lecture content. A series of short videos (5-10 mins each) on each topic were recorded and produced using the software package Camtasia © and low cost, consumer grade microphones. All of the slides were converted from a 4:3 to a 16:9 aspect ratio to provide full screen viewing on modern smart phones and monitors. YouTube was chosen as the primary means of delivery for the videos, due to its ease of accessibility and its built-in analytics, allowing the channel owner to monitor viewing trends such as average views between dates and retention rates. A role email account was set up as a means of hosting this dedicated YouTube channel (Wordley, Taylor and Jones, 2014), which allowed multiple staff to add and edit content, and for this content to be permanently associated with the unit, rather than tied to an individual staff member. Zipped versions of the videos were made available to students for direct download from the Learning Management System (Moodle) so that they could be watched offline or archived for future reference. Both PowerPoint and PDF versions of these slides were also provided on Moodle for student reference and revision.

Pre-class Quizzes

Online Moodle quizzes were developed in order to assess basic understanding and recall of the pre-workshop video content and major themes. Approximately six multiple choice questions were randomly selected from a larger question bank, for each topic. Students were given two attempts, within a 20 minute time period, with their best quiz result counting towards their grade. Each quiz was timed to close at the starting time of the associated workshop.

In-class Worksheets

The majority of the worksheet questions were evolved from tutorial problems used in previous offerings of the unit. Alterations were made to suit the new workshop format, and the 2 x 1 hour workshops scheduled each week. Questions which previously required the completion of A3 hand drawings were resized or broken into multiple components to fit in an A4 format, which was considered necessary given the limited work areas provided by lecture theatre desks. Students were required to write their names on the front of each worksheet to discourage ‘recycling’ of worksheets by students in future offerings. Spare or replacement worksheets were provided in the tutorial times and digital versions were also made available for download and printing by students. Formal solution sets to these worksheets were provided to tutors, but not students. Worksheets were only assessed and stamped for a time period of two weeks after the related workshop. Beyond this point feedback would be provided but no stamp.

Workshop Presentation Slides

Workshop slides (PowerPoint presentations) were produced, and used to very briefly revise the key messages from the pre-workshop videos at the start of each workshop (maximum 5 minutes). More importantly, the presentation slides were used to guide the class through each of the worksheet questions and provide assistance and sample solutions. Students were allowed a maximum of 3 minutes to work on a specific element of a problem. Count down timers were provided in the slides for visual reinforcement and to help keep the teaching staff on schedule. During these work periods, students were sometimes advised to work on their own in silence, but much more commonly to consult with the students sitting next to them. Students were strongly encouraged to sit with their project teams, as some activities focused on elements of the major team project. During these working times the teaching staff would circulate around the theatre to monitor progress, motivate students and answer questions. At the conclusion of each short work period, full attention was refocused on the teaching staff, who might then discuss the solutions (both correct and incorrect), highlight examples from the class, or solicit responses for certain students. Overhead projection and digital inking was sometimes used to illustrate different approaches. Projected content and instructor voice audio was automatically recorded to an online lecture capture system and provided to students to stream live, or download and review after the event.

Results and Discussion

Student Survey

An anonymous online student survey was used to capture detailed feedback on the new teaching model. Opinions were gathered on satisfaction with the videos, workshops, worksheets, and quizzes. Opportunities for open ended comments were provided to allow students to provide extra detail and suggestions on possible improvements to the resources and teaching model. A 7 point Likert scale was generally provided for respondents to identify their level of agreement with each statement. The survey (developed using Google Forms) was made available via the unit’s Moodle page and private Facebook group. Ethics approval for this study was granted (Project Number: CF14/1510 – 2014000711).

Teaching Resources and Activities: Student Engagement and Feedback

Pre-class Videos

A total of 46 videos were created over the course of the semester to replace the previous lecture delivered content. The total run time of the videos was 431 minutes, which was less than half time previously allocated to the delivery of this content in lectures (assuming 45 minutes of content delivery per hour of lecture). The videos obtained 14,359 views on YouTube alone during the first semester and up until the start of the exam period. This is an average of 312 views per video, which was only slightly less than the total number of students enrolled in the unit (~350). An example of a typical distribution of daily views over the course of the semester and into the exam period for a single video (Detail Drawing 1) is shown in Figure 1 below.

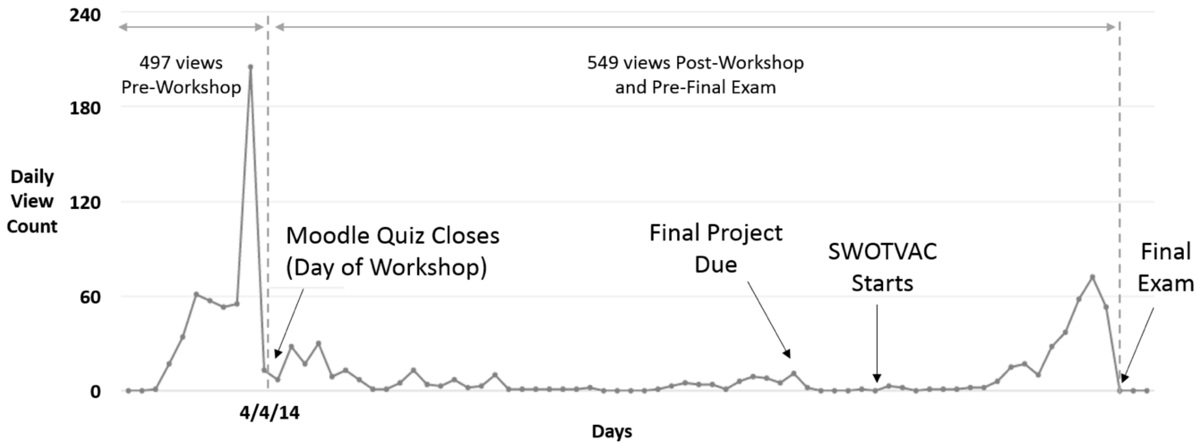

Figure 1: Daily YouTube view counts for the video *Detail Drawing 1*

This video was scheduled in week 4 of semester, so students had generally established a routine for the flipped classroom by this time. The graph indicates that most students watched this video the day before the related workshop and the closing of the associated online Moodle quiz. Some revision views are evident in the following weeks as the class attempted lab activities on this topic, and towards the end of semester when the final project was due. A second peak in revision views is evident just before the final exam. This viewing pattern was typical for all videos which had an associate Moodle quiz. As a test case, one set of videos was presented with no corresponding quiz component, this resulted in a significant drop in views: down to 99 views per video in the set, a 68% reduction. This indicated that the marked quizzes were a significant factor in motivating students to watch the videos.

In terms of playback device preferences, YouTube metrics indicate that 95% of all views were made via a computer, with only 3% on tablets and 2% on mobile devices. Survey data provided further insight with 74% of preferred computer users utilising a laptop, versus 21% on desktop machines. This finding suggests that it may be acceptable to compromise smart phone readability to provide greater detail and smaller text in future video production.

From the survey, 77% of respondents reported that YouTube was their preferred method for viewing the videos, while only 14% preferred downloading them from Moodle to watch offline, and a further 9% who primarily watched lower resolution versions embedded directly within the Moodle page. Open ended comments supported anecdotal observations of students skipping to key material in the videos and also watching them at faster playback speeds (1.5 times speed was most common among native English speakers).

Retention rates, defined as the percentage of the complete video watched for each view, was examined using YouTube analytics. Shorter videos (less than 5 mins) were found to have on average slightly higher retention rates than longer videos (49% compared to 42%).

From the student survey 88% of students agreed that *"the videos were effective for learning new concepts"*. Additionally 86% agreed that *"the videos prepared them for the workshop activities"*.

Pre-class Quizzes

A total of 13 quizzes were developed, each corresponding to a particular topic or video series. An average of 327 students completed each quiz which equated to 93% of the cohort across both campuses. The average mark on these quizzes was 92%.

From the survey 81% of students agreed with the statement "*marks from the quizzes motivated me to watch the videos*." This further confirmed the initial hypothesis that assessed quizzes would help to motivate students to review the recommended pre-workshop learning materials.

Workshops (In-class Activities)

A total of 17 flipped classroom style workshops were run over the course of this unit. Two teaching staff (the unit coordinator and a senior demonstrator) were used to deliver the workshops to the Clayton cohort of 250 students. Clayton workshop attendance (only) was estimated by printing a set number of worksheets and then counting the number remaining at the end of the workshop. This method was subject to errors (approximately ±10%), but provided a reasonably consistent indication of student attendance. On this basis, the average workshop attendance was 80% for the Clayton cohort, with a standard deviation of 9.3%. Workshops earlier in the semester attracted slightly higher attendance (maximum of 90%) than ones later in the semester (minimum of 70%) as shown in Figure 2.

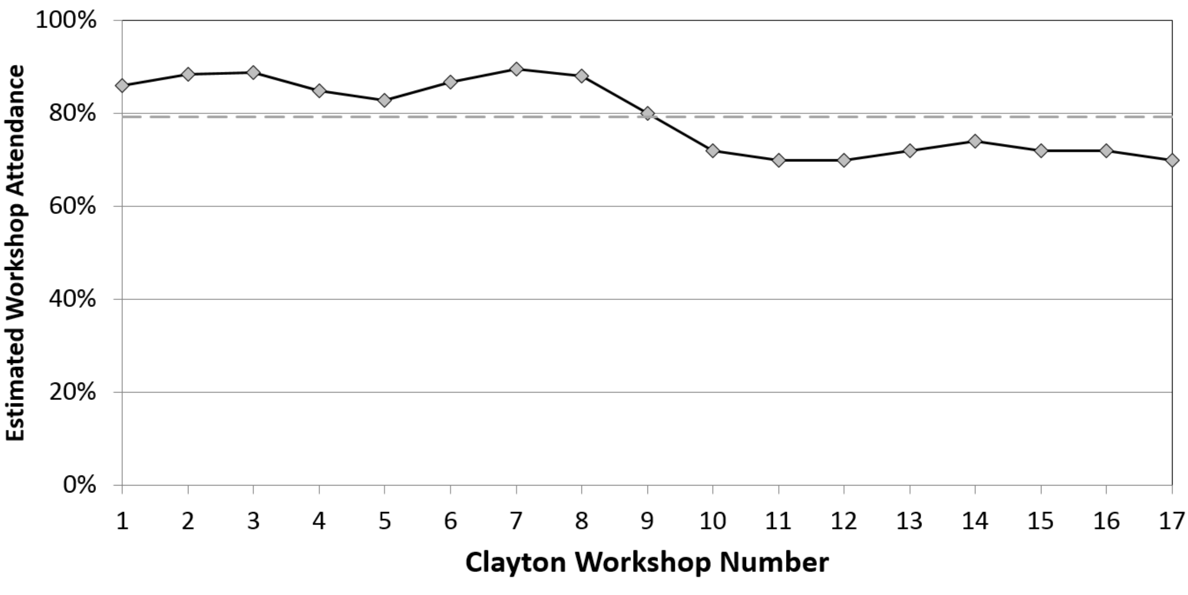

Figure 2: Estimated Clayton workshop attendance rates

From the survey, 86% of respondents agreed that having assessed worksheets to complete during workshops motivated them to attend. Online workshop recordings received an average of 36 views over the semester, and the variance was similar to that observed with workshop attendance, with slightly higher view counts at the start of semester and lower at the end.

In-class Worksheets

On average, students completed, retained and presented 92% of all worksheets, which equates to slightly less than 16 out of the 17 provided. This was considered a very high level of engagement considering the small amount of marks available (only 8% in total). A common theme from the open survey comments was that, in spite of the higher than average workload, students appreciated being forced to stay up to date with the content via the small regular assessments, rather than being allowed to defer their learning until the exam period. 87% agreed that the feedback provided by tutors during the marking of their worksheets was beneficial to their understanding of the material.

Student Responses

Overall there was a very positive response and strong student support for the implementation of the flipped classroom model in this unit. In response to the statement, *"In future I would like to see similar flipped classroom' teaching models implemented into other engineering subjects"*: 90% of respondents agreed, 55% strongly (highest scale increment). Only 4% of students disagreed with this statement. Students were also asked to rate their satisfaction with the flipped classroom teaching model used in this subject. 93% of students reported satisfaction, with 51% very satisfied.

The positive survey results were also supported via the Monash SETU quantitative evaluations and written feedback. In 2013 the median score for subject satisfaction at Clayton was 3.91 out of 5. In 2014, the first flipped offering this increased to 4.73. The median student opinion of the learning resources provided increased from 3.99 to 4.69 and the response rate lifted from 39% to 64%. The majority of positive written comments (53 out of 97) were in relation to flipped classroom. Only 4 out of 68 of the 'in need of improvement' comments related to the flipped classroom.

Student Learning Outcomes

In an attempt to identify changes in student learning outcomes two final exam control questions were used to compare class results before and after the switch to a flipped teaching mode. The entire exam was worth only 30% of the unit mark, with each control question contributing 12% of the total unit mark. It is worth noting that the majority of students were very close to, or had already passed the unit coming into this exam, based on 70% of the unit marks being allocated in-semester. In order to remove as much uncertainty from the exam question comparison as possible, the questions were carefully tested by teaching staff to try and ensure that they examined the same content and were a similar level of difficulty. The results are summarised in Table 1.

Table 2: Control question 1 represents Detail Drawing and question 2 Assembly Drawing.

	Control Question 1		Control Question 2	
	Average Question Score	Coefficient of Variance	Average Question Score	Coefficient of Variance
Traditional Model	66.5%	0.31	57.8%	0.47
Flipped Classroom Model	64.5%	0.28	65.9%	0.35
Change in average	-2.0%	-0.03	8.1%	-0.12
Percentage change	-3.0%		14.0%	

A two tailed T-Test was used in order determine the statistical significance of these results. For question 1 the T-Test returned 0.21, indicating that the change in average was not significant and hence the null hypothesis cannot be rejected. Question 2 returned a T-Test value of 9.6×10^{-5} suggesting that the change in average was statistically significant. Given the additional uncertainties and uncontrolled factors between these two cohorts, it is reasonable to conclude from these results that no significant difference in learning outcomes can be observed.

Conclusions

A flipped classroom teaching model was implemented in a large (n= 350), multi-campus, second year engineering design unit. Assessed pre-workshop quizzes (average 92% completion rate) were found to be effective in motivating almost all students to review short pre-recorded lecture videos and successfully demonstrate basic comprehension of this content (average 92% correct answers). View counts were observed to reduce by 68% for videos which did not feature a corresponding assessed quiz. Pre-class videos were most commonly streamed direct from YouTube (~77%) and viewed on a laptop computer (~70%), and anecdotal comments indicate that playback speed was often increased (most popular being 1.5 times speed). Short videos (less than 5 minutes) and those earlier in a series produced slightly higher retention rates. Videos that featured examinable content received significant revision views, on average around 2 per enrolled student. Assessed active and cooperative in-class (workshop) activities are thought to have contributed to significantly increased student attendance rates throughout the semester compared to previous offerings. Students satisfactorily completed and submitted 92% of the workshop activities undertaken in this time. An attempt was made to measure any differences in learning outcomes following the implementation of the new model, but it was considered that no significant improvements were evident due to uncertainties in this process. Student support and satisfaction with this flipped classroom implementation was very strong with a 93% approval rate and 90% of respondents enthusiastic to see it applied in other subjects. Formal quantitative measures of student satisfaction and perceived unit quality all improved significantly following the changes. Following this positive response, staff are working to implement similar teaching models in other units within our Faculty.

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