Baby steps towards flipped learning

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Structured Abstract

BACKGROUND
This study reports the efficacy of using a flipped learning approach for teaching third year engineering students the fundamental elements of machine design. The flipped delivery style was deliberately employed with minimal changes to the teaching media (lecture notes, problems sheets and assignments). If such a change is effective in improving student engagement and outcomes without an onerous additional teaching burden then the flipped learning approach could be encouraged more widely.

PURPOSE
The purpose of this study is to establish whether a flipped learning approach could be used to improve student learning outcomes within a course with only a modest change in taught content. A favourable outcome would give support to more widespread adoption of the flipped learning approach.

DESIGN/METHOD
The topics chosen for this study were related to machine design as taught to 3rd year Bachelor of Engineering students in the Mechatronics and Product Development disciplines. Previous teaching practice (up to and including the 2012 cohort) involved class-room lectures and tutorial sessions. Assessments comprised a final exam and an assignment on mechanical design of a transmission system (comprising gears, belts and chain drives, shaft design and bearing selection). Difficulties encountered with this approach by the author will be enumerated.
Flipping of the teaching (for the 2013 cohort) involved the use of video lectures and worked solutions viewed by the students outside class time. Class time was occupied by tutorials and discussion, with the students working through the assignment in groups in the class with the lecture assignments timed with their progress. The flipped cohort's performance was compared to the conventionally taught cohort in the final exam and the test administered to the flipped cohort.as a final examination.

RESULTS
The performance of the flipped cohort in the power transmission assessments (which was taught directly by the in-class assignment) was better than the conventionally taught cohort. Comparing only performance in the exam questions the difference was statistically significant. For another topic (fatigue design) that was taught using the flipped approach (but without the use of the in-class assignment) the flipped cohort's performance was better but the difference was not statistically significant.
The use of the assignment as an in-class activity (rather than outside class) gave students the opportunity to work in groups (without the disadvantage of teasing of individual performance from group performance) and allowed an immediacy of feedback previously impossible.

CONCLUSIONS
A flipped teaching approach for mechanical design gave student competence levels (as assessed by exam performance) that was at similar levels to or exceeded that of students taught in a conventional manner. The findings of this study suggest that the favourable outcomes of the flipped learning approach can be obtained with only small changes to a conventionally taught course.

KEYWORDS
Flipped learning; Machine element design.

Introduction

Teaching practice has recently seen a movement away from traditional “teacher-centred” approaches towards more “learner-centred” approaches. One such approach is termed “Flipped learning” – an approach initially developed for pre-tertiary teaching (Bergmann & Sams (2012)) but seeing increasing use in tertiary teaching - as reviewed recently by Hamdan et al (2013) and Yabro et al (2014).

While there is no hard and fast definition of flipped learning, the approach utilises technology to move direct learning (lectures for example) out of the group teaching space. Instead the group teaching interactions comprise more engaging and collaborative activities (examples of these activities are summarised by Hamden et al (2013)). The direct learning is conducted in an individual setting – typically by students on their own or in small groups.

Pearson publishing and the Flipped Learning Network (2013) identified the following four key features (termed the four pillars) of flipped classrooms:

1. Flexible Environments – to accommodate a number of different teaching and learning activities.
2. A Shift in Learning Culture – from teacher centred to student centred.
3. Intentional Content – ongoing consideration of what strategies can maximise class time.
4. Professional Educators – that determine how to maximise the value of class time and provide students with ongoing feedback.

Use of terms such as “pillars” can give the impression that a large degree of institutional buy-in is required for the adoption of flipped teaching approaches. It can be seen from the list above however that (with the possible exception of item 1) an individual educator could implement flipped teaching within a course/paper.

Evidence of the efficacy of flipped teaching is somewhat mixed – in many cases any improvements in student performance are small and/or insignificant (see the extensive reviews in Hamden et al (2013) and Yabro et al (2014)). In engineering teaching Redekopp & Ragusa (2013) reported a small improvement with the use of flipped learning in computer engineering with subsequent modifications to the approach yielding larger improvements. In a similar study, Amresh et al (2013) found learning benefits for a flipped approach to teaching computer science but with some pitfalls on student experience. Braun, Ritter, & Vasko (2014) on the other had found that for engineering mathematics, students viewed the flipped approach favourably but that exam performance was not changed compared to the traditional teaching approach. Mason, Shuman, & Cook (2013) reported that students learning control engineering in a flipped classroom preformed as well as, and in some areas significantly better than, students taught in a traditional classroom. Thomas & Philpot (2012) reported no significant difference between traditional and flipped approaches to teaching mechanics of materials despite the extensive support materials developed.

The purpose of this study was to determine the efficacy of a flipped teaching approach to the teaching of machine design within a third-year professional engineering course. A particular need was to keep the modification of developed content to a minimum for two key reasons:

- So that the additional workload was not excessive given the limited buy-in by other staff.
- So that the flipped approach could be used in a multi-teacher/multi-campus environment where other staff wished to keep a more traditional teaching approach.

If successful, this study could lead to the flipped learning style being more widely adopted.

Background

The course selected was “Mechanical & Manufacturing Engineering” taught at the author’s institution to third year Bachelor of Engineering students in the Mechatronics and Product Development majors. The content was split nearly 50-50 between Manufacturing Processes (taught in the first half of the semester) and Mechanical Design (taught in the second half of the semester). The flipped learning approach was adopted for Mechanical Design which was split into three key topics:

1. Fundamentals – theories of failure, power and work
2. Fatigue design – S-N curves, fatigue strength factors, stress concentrations and Haigh (constant-life) diagrams.
3. Power Transmission – Gears, Belts, Chains, Shafts and Bearings

The teaching of power transmission often falls into two distinct camps – practical design, build and test approaches and a more fundamental approach. In the case of the former the short timeframe often precludes a detailed design and instead components are selected based on availability and familiarity. The latter approach is criticised for not teaching some of the more practical aspects of mechanical design.

Starting in 2011 the author used an assignment to take students through basic aspects in the design of a simple transmission system to take students through the basic procedures (utilising both fundamental principles as well as codified procedures) in selecting and designing the key elements – bearings, shafts, spur gears, chains and belts. Feedback gathered in 2011 showed that the students found this context-rich assignment both challenging and rewarding. Reflection on student performance by the author however identified shortcomings – particularly in the opportunities for feedback (both formative and summative) to be given to students. These shortcomings were one of the key drivers for adoption of the flipped learning approach.

Methods and Approach

Modifications to the content for flipped learning (the 2013 cohort) compared to the traditional approach (the 2012 cohort) are summarised in Table 1. For the flipped learning approach video lectures were developed based on the Microsoft Powerpoint presentations from the previous year. These were narrated using Adobe Presenter and the resulting presentations

Table 1. Comparison of in-class, assessment and outside-class activities for the traditional teaching and flipped teaching cohorts.

	Traditional (2012)	Flipped (2013)
In-class activities	Lectures Tutorial Problems	 Tutorial Problems Assignment
Assessment activities	Assignment Final Examination	 Final Examination Test
Outside-class activities	Problem Sheets Self-directed Readings Revision	Problem Sheets Self-directed Readings Revision (Video) Lectures

were published as standalone Flash-embedded portable document format (pdf) files on the Stream site (Massey University's Moodle-based virtual learning environment). The total time taken to prepare these narrated lectures was around 20 hours. A test was given on the power transmission material – this was the only new element developed for the course.

The power-transmission assignment was used as an in-class activity with students working in groups. Discussion within groups and sharing or ideas and problems between the groups was encouraged by the author. The assessment of each student's learning of the topic by a test however meant that the benefits of groupwork were realised without the need to tease out individual contributions/learning.

A typical in-class session would start with a re-cap on key features of the topic from the narrated lectures. This was followed by a few key problems conducted in a tutorial fashion. Once the students were familiar with the application of the concepts to mechanical design the groups applied the topic to the in-class power transmission assignment. This did require a change in the order of the topics/concepts for 2013 so as to better match the stages required for the power transmission assignment.

Student learning was judged by comparing performance on specific test and examination questions that covered specific aspect of the course, namely:

- Fatigue Design – included in the 2012 and 2013 final examination
- Power Transmission – included in the 2012 and 2013 final examination as well as the 2013 in-semester test.

The author took great care to ensure that the questions were of a similar technical degree of difficulty and that the 2013 cohort were not aware of the intention to compare their performance to the 2012 cohort in a direct question-by-question way.

Student engagement was assessed qualitatively by the author's observations of the class. An attempt to quantify student engagement was made by using access logs to quantify the number of times that students accessed the online material.

Results

Student Learning

Student marks in all summative assessments were found to be approximately normally distributed. The comparative performance of the students in the power transmission and fatigue design topics is compared in Table 2 and Table 3 respectively. In all cases the 2012 performance was based on questions in the final examination. For power transmission the 2013 cohort showed an improved performance in both the test and the final examination. In the case of the latter the improvement was significant to better than $p=0.01$. By contrast for the fatigue design topic, the 2013 cohort's improvement was not statistically significant.

Student Engagement

The number of times the content related to the mechanical design aspects of the course by the end of each week is shown in Figure 1. For the fundamentals content the number of views was low. For the fatigue design and power transmission content students began to access the material in parallel with or even ahead of the in-class activities. The content was accessed again ahead of the test and the final examination.

Engagement of students during in-class activities was not noted to be appreciably different between the two cohorts – although this could be due to the informal way in which this was assessed, and the generally high engagement many students felt with mechanical design topics.

Table 2. Comparison of student results (marks out of 20) in assessments related to mechanical power transmission.

Cohort	Assessment	Number attempting	Lower Quartile	Median	Upper Quartile	p
Traditional (2012)	Exam Question	64% (18/28)	7	10	11.75	----
Flipped (2013)	Test Question	100% (28/28)	7.75	12	17	0.06
Flipped (2013)	Exam Question	86% (24/28)	14.75	16.5	18	<0.01

The p-value compares the performance of the 2013 cohort to the 2012 cohort performance in the exam question using the student-t test.

Table 3. Comparison of student results (marks out of 20) in assessments related to fatigue design.

Cohort	Assessment	Number attempting	Lower Quartile	Median	Upper Quartile	p
Conventional (2012)	Exam Question	79% (22/28)	10.25	13.5	15.75	----
Flipped (2013)	Exam Question	82% (23/28)	11.5	15	17	0.19

The p-value compares the performance of the 2013 cohort to the 2012 cohort performance in the exam question using the student-t test.

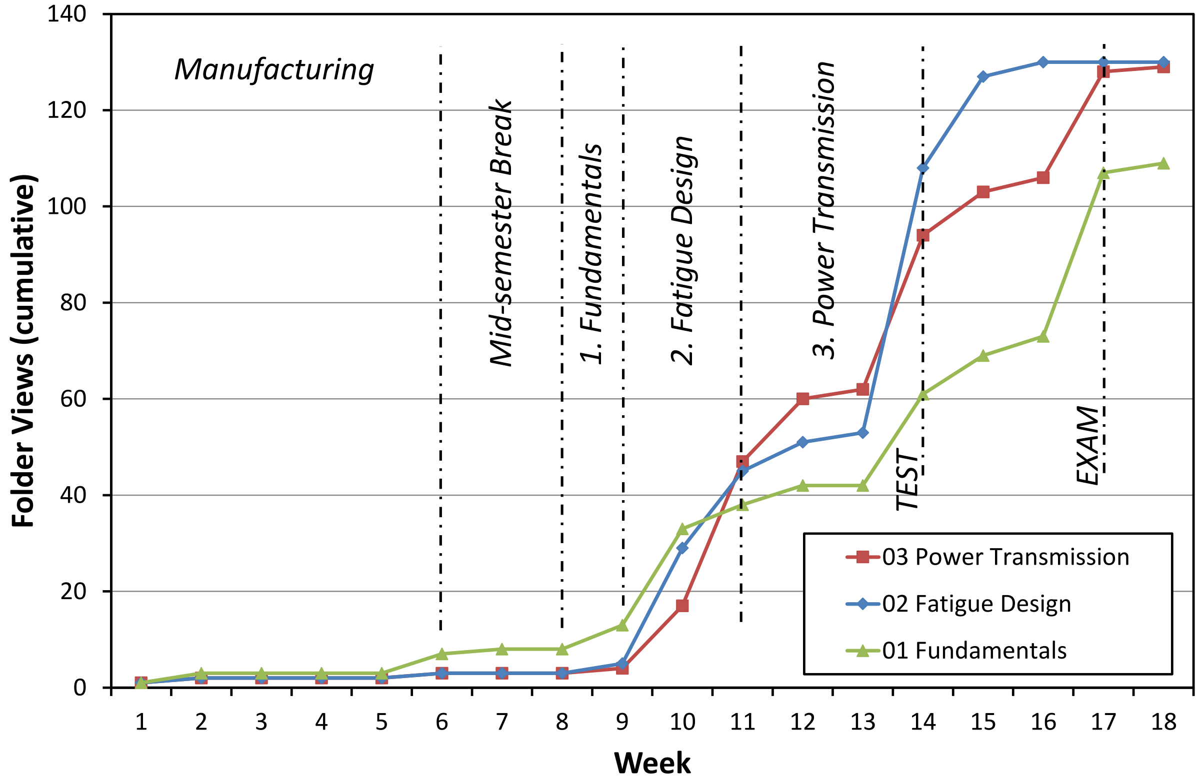

Figure 1. Cumulative folder views by the end of each week of teaching. Also shown are the teaching topics during the course and the test and final examination timings for the course.

Discussion

Learning of students with the flipped approach

For the power transmission topic, the flipped cohort's performance in the 2013 test was superior to the traditional cohort's performance in the 2012 exam, although the difference fell short of being statistically significant ($p=0.06$). It should be noted however that all students took the 2013 test while the exam question represents a self-selecting subset of students (for both 2102 and 2013 cohorts). Assuming that students who felt less confident in power transmission were more likely to avoid the exam question, then the improved performance in the 2013 test can be considered significant. The flipped approach seems to have been successful therefore in increasing student competence in analysing mechanical drive systems.

The power transmission examination performance for the flipped 2013 cohort was significantly ($p<0.01$) better than the traditional 2012 cohort. In this case some of the improvement could be attributed to the flipped approach but there are additional possibilities including:

- The test question in 2013 could have better prepared the students for the exam question in that same year.
- The improved feedback from the test could have enhanced the 2013 cohort's learning of the topic. The reduced marking time for the tests allowed a rapid turn-around for the 2013 cohort compared to the assignment marking for the 2012 cohort. This reduction in marking time offset the additional workload in preparing the video lectures and setting the test for the flipped 2013 cohort.
- Enhanced learning and retention brought about by testing as reported by Roediger & Karpicke (2006).

For the fatigue design topic a small but not significant improvement was observed between the exam performance for the flipped 2013 cohort and the traditional 2012 cohort. The performance of the traditional 2012 cohort in the fatigue design topic was however relatively strong so that substantial improvements are more difficult to achieve. Additional possibilities for the smaller improvement could be that fatigue design was not included in the semester test, or that the in-class activities for fatigue design did not include a context-rich assignment as used for the teaching of the power transmission topic. Regardless, the flipped approach gave student outcomes (as measured by examination performance) in fatigue design at least as good as that given by the traditional approach.

Student Engagement

Initial views of the fundamental support material on Stream were low, despite students seeming to be well engaged in class. This effect was short-lived and by the time the in-class assignment was being done (power transmission) students were accessing the on-line lectures and problem sheets well in advance of the associated in-class activities. The initially low engagement with the online material was attributed to the students being unaware of the expectations (suggesting that courses using flipped learning were rare for this cohort). Thereafter however the students engaged with the material in a timely manner.

Students re-engaging with the online content ahead of assessments is a further advantage for student learning. In traditional courses while notes are available for revision the lecture itself was not. This observation also however hints that assessment itself guarantees more engagement with the course content and concepts.

Concluding Remarks

A flipped learning approach was applied to the teaching of mechanical design in 2013 and the performance of the 2013 cohort was directly compared to that of the 2012 cohort who had been taught the same content in a more traditional lecture-based approach. Despite only modest changes to the actual content delivered (only the modes by which it was delivered – accounting for approximately 20 hours of lecturer preparation time) improvements were observed for all of the topics compared – in some cases highly significant improvements.

The elements of the traditional course that were adapted to the flipped learning approach, namely lectures, tutorials and an assignment were modified as little as possible. The results of this study suggest that for a great many engineering courses/paper (which comprise similar elements to the course used for this study) the flipped learning approach could give better learning outcomes with only modest additional instructor effort.

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