Introduction

Numerous studies have found that student attention span during most lectures is roughly fifteen minutes (Wankat, 2002) and after this period, the number of students paying attention begins to drop off dramatically. This drop-off results in a retention loss of lecture material and can negatively impact learning outcomes (Prince, 2004). Nevertheless, the traditional didactic lecture is still seen as an efficient, but not necessarily effective, means of teaching large numbers of students. Material can be delivered at a predefined pace to a student audience, and it is difficult for the lecturer to encourage participation when aiming to cover all essential material during the lectures.

Learners, however, are "constructors of knowledge" in a variety of forms. In particular, they take an active role in forming new understandings and are not just passive receptors (Grabinger & Dunlap, 2002). The concept of active learning appeals to this activity in forming new understandings and is generally defined as any instructional method that engages students in the learning process. Its core elements are student activity and engagement in the learning process (Biggs & Tang, 2007) (Bonwell & Eison, 1991), including student-posed questions and spontaneous discussions that encourage staff-student interaction and lead to increased feedback within the classroom. Traditionally styled didactic lectures may offer little in the way of these active learning opportunities.

The 'flipped' or 'inverted' classroom approach attempts to bring the effectiveness of active learning to the lecture venue by shifting the onus onto students to study the relevant material, which would ordinarily be covered in lectures, at home. Evidence suggests that this approach engages a wider spectrum of learners (Lage, et al, 2000; Mazur & Crouch, 2001). In the context of engineering education, the flipped approach allows lecturers to work with students when the most important aspects of learning take place: applying theory to and reasoning through problems. This alters the focus of education from information transfer to helping students assimilate material and better develop complex skills (Mazur, 2009). Typically in such an approach, the face-to-face, in-class sessions are designed to be more informal and interactive, with the goal of removing the disconnected feeling of the traditional didactic lecture and replacing it with an environment where students will be encouraged and expected to participate. This can include mechanisms like clickers or web/mobile-based surveying and feedback to enhance the interaction.

In this paper, a trial implementation of a flipped classroom is described as applied to a large first-year subject. Several forms of evaluation were undertaken, including usage statistics, student surveys, focus groups and feedback from teaching staff in order to better understand the student experience and potentially expand such an approach to other subjects within the School of Engineering.

Background

Studies have shown students' expectations about, and relationships with universities have changed markedly in the last two decades (James, Krause, & Jennings, 2010). Students now participate in a mass education system that is considerably more diverse than it was 20 years ago and are increasingly time-poor with many now juggling employment, social activities and family responsibilities while studying. As a consequence, students are coming on to campus less, have fewer contact hours and are relying more heavily on the Internet and digital tools to complete their studies. When they do come on to campus they are expecting high-quality and engaging classes that are effective in their learning of the subject material. The use of active learning techniques in engineering classes typically improves student engagement and generally leads to improved learning outcomes (Prince, 2004); in particular, the flipped classroom approach attempts to implement a highly structured active learning environment while also providing students with more flexible and convenient access to higher education through use of online video lectures and assessments.

In 2013, the author received a grant from the university's Learning and Teaching Initiative (LTI) fund to develop a pilot implementation of a flipped classroom for the first year subject ENGR10003 Engineering Systems Design 2, appealing to the "innovative and effective use of technology" priority area. This subject is compulsory for most Engineering students, comprises of Digital Systems, Mechanics and Programming modules and has an enrolment of around 850 students. The development of the flipped classroom curriculum for this subject would involve :

1. Basic theory and definitions to be delivered through well-crafted, concise, high-quality online video modules. These videos would involve the lecturer being recorded in front of a green screen that would be projecting the content slides. Post-production editing would allow animations, cut scenes and transitions to be inserted to improve the production value. The quality of these videos would be far beyond the in-lecture screen capture system currently in use at the university that simply captures what is being projected in class. These lecture modules could be reused each semester, used as revision for later-year subjects and even be made free and publicly available like many international universities do. High-quality video production equipment was purchased and a room outfitted to act as a video studio to perform the recordings.
2. The redevelopment of the face-to-face, in-class sessions to be more informal and interactive, providing an environment where students would be encouraged and expected to participate, as opposed to the traditional didactic lecture. Students will be better guided in problem solving approaches that further enhance conceptual thinking and reinforce theory learnt from the videos. The use of online video modules to deliver basic theory puts less constraint on face-to-face time with students and allows for more time to discuss and motivate the practical aspects of theory and further motivate the 'big picture' of the subject. It will also allow for increased posing and answering of questions, and even on-the-spot teaching adaptation to fill in any gaps or correct any misunderstandings.

The flipped classroom implementation would be a partial flip for the subject, with four lectures out of ten from the digital systems module selected to be converted to the flipped classroom approach, largely due to the limited time available to create the online videos. The outcome of such a partial flipping in itself could be useful to other subject lecturers that either do not have the desire to or are not able to completely flip their entire subject. This partial flipping would further allow the students to compare and contrast both the more traditional didactic lectures and the flipped classroom within the same subject module and lecturer.

Design of the in-class sessions

The 50 minute in-class sessions were identified to potentially serve four possible needs :

1. **'Big picture' review of concepts** : This serves to reinforce the video lectures and help students reason out concepts at the analysis level of Bloom's Taxonomy (whereas knowledge and understanding are the goals of the video lectures). The environment is informal and students can openly ask questions when a concept is not clear.
2. **Practice problems** : In the traditional lecture system, after spending time introducing concepts, there is limited time to apply them through examples and practice problems. Furthermore, it is difficult for students to apply concepts they have just learned in the preceding minutes of a lecture. The flipped approach solves these two issues: Firstly, it allows more time for examples and problem solving. Secondly,

students can actively contribute to solving these problems as they have previously seen the concepts by watching the video modules.

3. **Real-life examples** : The gap between theory and reality can be difficult for students to see due to their lack of experience. It is therefore important to illustrate the use of concepts that have practical every-day uses. Such real-life examples give the theoretical concepts a visual context that will serve as a great tool to engage students and spark their interest.
4. **'Just-in-time' teaching** : If feedback from the active learning environment or online video modules suggest that students are struggling with some concepts, just-in-time teaching (Biggs & Tang, 2011) can be adaptively deployed to fill these learning gaps. This is possible due to the inherent time flexibility of the flipped classroom approach.

The balance of the implemented in-class sessions is given in Table 1. Due to the absence of any feedback-generating assessment linked to the online video lectures, it was not deemed possible to implement any just-in-time teaching sessions – at least for this trial run of flipped lectures.

Table 1: Breakdown of in-class sessions

Session number	Content
1	Big picture / Practice problems
2	Practice problems / Real-life examples
3	Real-life examples / Practice problems
4	Practice problems / Big picture

Design of the online video modules

The online video lectures were designed to be short, concise and cover only one specific topic at a time. The duration of the videos was set at around 10-12 minutes; long enough to cover one particular topic and within the likely attention span duration of students. It was found that a regular 50-minute lecture could be broken into three concise 10-12 minute video lectures covering all necessary source material without needing to do any examples as they could be covered in-class. Unexpectedly, it was also noticed that the usual didactic lectures appeared to have inefficient periods of inactivity that were eliminated when converting to the shorter format videos.

Lectures were filmed in a "weatherman"-style format, with the lecturer presenting in front of a green-screen displaying the relevant source material. It was felt that the video lectures would maintain a formal lecture-style approach in order to sufficiently cover the basic theory and serve as a continued resource, with the in-class sessions providing a more informal and flexible learning environment. The inclusion of the lecturer was intended to give a more connected, personal touch with the students and allow physical gesticulations to highlight important points – something that a simple voice over or inset headshot could not provide.

A video was recorded for each slide, which gave the freedom of filming multiple takes to ensure a satisfactory delivery and did not require the presenter to have to manually advance the slides with a remote control in hand. Fading transitions between slides and any animations could be added in post-production to ensure a smooth and continuous final product.

Table 2: Breakdown of in-class sessions

Video number	Duration (min:sec)	Content	Prerequisite for flipped session
1	10:36	Digital basics	1
2	12:14	Source coding	1
3	11:46	Error control coding	2
4	10:17	Binary addition	3
5	10:35	Comparators	3
6	11:07	Programmable logic devices	4

The video lectures have further significant benefits :

- Students can learn on their own terms and speed, and this solves the attention span and retention issue of the traditional lecture system. Furthermore, students have time to think of questions and reason things out before the class. This can be a significant benefit in engineering subjects that are full of complex theory and abstract concepts that can be difficult to relate to reality.
- Current and future students who spend many hours online and rely heavily on the Internet in their day-to-day lives need such an adaptable system. Current students work more hours in part-time jobs and need access to effective, carefully constructed resources when doing their out-of-class learning. These videos effectively make the lectures accessible at all times and are excellent revision tools. Students may no longer feel disengaged because they have fallen far behind in the traditional lecture system due to time pressures.

Results and evaluation

The overall student response to the series of flipped lectures was evaluated using several measures including online video lecture viewing statistics, estimates of in-class attendance and level of participation, feedback from tutors and an end-of-semester student survey.

Video lecture viewing statistics

Unfortunately it was not possible to capture detailed video usage statistics directly from the Learning Management System (LMS) due to a technical issue but some basic usage summary data was able to be extracted, shown in Table 3. This shows that a reasonable number of students were preparing for the lectures by watching the videos before the associated in-class activity, keeping in mind that there was no explicit assessment based on watching the videos. Note that statistics on precisely when the videos were watched could not be captured (other than they were watched before the lecture), nor if a student watched all or only part of the video.

Table 3: Video lecture usage

Online video lecture	Number of students who viewed it before class (N = 853)
1	564
2	531
3	617
4	540
5	512
6	493

In-class attendance and participation

While in-class attendance was not specifically recorded, it appeared to at least be no lower than previous years with completely traditional lectures. The biggest change however was in the amount of and the willingness of student participation in-class. The informal nature of the flipped in-class sessions allowed a lot more freedom in exploring ideas and methods of explanation previously not possible due to time constraints on the delivery of content. For example, several important and abstract concepts were demonstrated by making students perform role plays amongst themselves and in front of the lecture theatre. One example that worked particularly well was using students as building blocks in a “human” digital comparator. Students could see at the micro level what was required to perform a one-bit comparison and could then see how they could be integrated with other student “blocks” at the macro level to build a larger functioning comparator.

Furthermore, students appeared to be much better prepared with more considered questions and were much more willing to interact and interrupt the class when they had a question. This is in stark contrast to the regular lectures, where students are bombarded with theory and examples and are usually too busy writing things down to poke their head up to ask a question. It gave the lecturer the feeling that students had been reading ahead in the notes ahead of class and were treating the in-class sessions as true active learning participatory activities.

Student surveys

At the end of the semester, an optional, anonymous survey was given to students to gauge their experience and the effectiveness of the flipped classroom approach. The format of the videos was chosen such that the full body of the lecturer is usually on the screen presenting and using the slide background to illustrate the main points in a similar fashion to a television weather presenter. At the end of semester, students were asked if they felt that having a physical person in the videos makes a difference to their learning compared to just a voice over and use of a digital pointer, the results of which are given in Table 4. This question was asked to see if the there was added value in having a person in the videos who actually uses physical gestures as opposed to using a voice-over and digital pointer, which is significantly less work to produce. Results show that the physical presence of the lecturer is highly valued by students in ENGR10003.

Table 4: Video lecture presenter presence

Presence of physical person in online video lecture	Number of responses (N= 246)
Strongly agree	130
Agree	74
Neither	20
Disagree	20
Strongly disagree	2

Students were asked to indicate how much the in-class sessions had helped reinforce the subject material and enhance their learning, with the results given in Table 5 for the subset of students that responded that they had watched more than “little or none” of the video lectures before the associated in-class session. These results show that the students found the in-class sessions valuable to enhance their learning. Students were also asked to indicate their preference for the type of in-class session, the results of which are given in Table 6. These results indicate that students overwhelmingly prefer to spend the in-class time doing practice problems, which is likely due to this appearing most beneficial to them as preparation for the final exam. The ‘big-picture’ review of concepts was the highest scoring second preference, indicating that students preferred to see things from a higher level once they had engaged in some practice problems.

Table 5: Student perception of impact of in-class sessions

In-class sessions helped reinforce material and enhance learning	Number of responses (N= 224)
Strongly agree	71
Agree	119
Neither	19
Disagree	13
Strongly disagree	2

Table 6: Student preferences for in-class session type

Option	Responses for 1st preference (N= 246)	Responses for 2nd preference (N= 246)
‘Big-picture’ review of concepts	64	105
Practice problems	131	67
Real-life examples	51	74

The official university end of semester Subject Experience Survey (SES) yielded many student comments that praised the online video lectures and corresponding flipped lecture sessions. Some students pointed out that despite not watching the online video before the lecture, they obtained a basic understanding from the “applied perspective” in class and then preferred to go back and view the actual theory via the online video lectures. Several students commented that they preferred the informal nature of the in-class sessions to the traditional lectures and consequently felt more willing to contribute in class. Students also commented on the usefulness of the video lectures as revision tools for the exam, although statistics on video views were not able to be gathered during this period.

Discussion

The flipped classroom trial received a very positive response as indicated in the student surveys and the anecdotal in-class evidence showed students were better prepared and participating with a higher level of understanding than in previous years. As it was only trialled over four lectures out of ten for the digital systems module (out of thirty six total lectures for the subject), the impact on academic results is difficult to ascertain compared to previous years for the subject and doesn’t reveal any major differences. Once the lectures are expanded to cover more of the subject an interesting study would be to also analyse the academic results of the students entering follow-on subjects, where ENGR10003 is a pre-requisite to measure any improvement in their entry knowledge.

The survey results clearly indicate that students want to spend the in-class time revising concepts and doing practice problems, which is likely to better prepare them for the final exam. In light of this, the plan is to design more of these flipped classes, in conjunction with providing additional online video lectures to further increase student engagement.

Further data obtainable from the Learning Management System (LMS) will help indicate if students are watching videos according to the prescribed schedule and give a more detailed idea of the usage patterns. If an online quiz after video modules is used, this data could not only indicate who has watched the videos and when they did, but also the level to which the students have understood the concepts. Just-in-time classes could then be scheduled that are dynamically created according to the results of these quizzes. Questions as to what the assessment should be based on, how much it should be worth and when it should be held would have to be examined.

Conclusion

The increasing use of active learning in engineering education as an effective means for teaching and learning through improving student engagement naturally means that the traditional didactic lecture needs to evolve in order to support this paradigm. It is also evident that strategies must be developed to overcome students’ changing time and space constraints and support their learning through better use of technology. The production of online video lectures and consequent ‘flipping’ of the lecture theatre to better provide an active learning environment has allowed a more guided setting for students to exercise higher levels of understanding involving analysis, evaluation and synthesis. The flipped classroom implementation, while being a limited trial in one (large) subject, has shown to have the potential to improve student engagement which would suggest improved teaching and learning outcomes. It is envisaged that further lectures in ENGR10003 will be flipped, with the future goal to further expand the approach to other large subjects that follow-on from ENGR10003 to maximise the impact and benefits that a flipped classroom approach can bring.

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