

## **Flipped classroom learning in a first-year undergraduate engineering course**

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**Abstract:** Flipped classrooms support student-centred learning and are increasingly being adopted in institutions of higher learning worldwide. This paper is a report on the findings of a two-year funded project conducted on the impact of adopting a flipped classroom approach on first-year undergraduate engineering students' learning in a New Zealand university. A design-based methodology was adopted to allow for five iterative course refinements. Data collected through student achievement data, surveys, focus group interviews, observations and video analytics of student video-watching behaviour indicated a significant improvement in students' learning and that they valued the flipped course components such as the lecturer-created instructional videos, in-class problem-solving exercises and continuous assessment in supporting their learning. However not all students prefer learning through this approach and more scaffolding is needed for first-year students to take up responsibility for their own learning. Implications for practice are offered.

### **Introduction**

Flipped classrooms have gained increasing interest and are rapidly adopted in universities and learning institutions worldwide. The flipped classroom is an active student-centred educational approach which typically requires students to prepare for class – through readings, pre-assessments, or watching videos – in order to gain basic information in their own time, prior to attending class/lectures. The class/lecturer time is thus freed up for students to apply the knowledge through problem-solving activities with guidance from the lecturer/teacher (Strayer, 2012). Flipping the focus of class time allows students to take increased responsibility for their own learning through active investigation both in and outside of class time. This changes the class time focus and dynamics from the transmission of knowledge to one involving collaborative, interactive learning and just-in-time teaching (Bonk & Khoo, 2014). It provides more flexibility for lecturers and students to participate in discussion and collaborative and guided problem-solving activities in ways that are known to address student misconceptions and support the mastery of threshold concepts (O'Toole, 2013).

Within each academic discipline there exists core concepts that once grasped can reveal new and previously inaccessible ways of thinking about that subject. These TCs (Meyer & Land, 2006), are hard-to-grasp, troublesome, and are often where students 'get stuck' (Harlow, Peter, Scott & Cowie, 2014), yet students need to master them in order to think and act like a subject specialist. By designing their pedagogy to target the teaching and learning of TC content, educators can optimise student learning outcomes.

This paper reports on a two-year funded research project conducted to investigate the impact of adopting a flipped class approach on student learning in an undergraduate engineering course that involved threshold concepts. The next sections of this paper will describe the study context of interest, the design and planning of the flipped class approach in the study and emerging findings on the impact of the approach on student learning.

### **Research Context**

The "Introduction to Electronics" course is a compulsory undergraduate course for engineering students at the University of Waikato, New Zealand. It has a typical enrolment of approximately 150 first-year students and is co-taught by two lecturers. The course introduces students to several key TCs relating to analog electronics in the first section. This section is taught by Lecturer 1. The second section of the course focuses on ideas related to digital electronics which is taught by a second lecturer (Lecturer 2). The course is regarded by many students to be a conceptually challenging one with a relatively heavy conceptual load, particularly in the analog electronics section. The organizational model for this course has traditionally consisted of three one-hour long lectures, an hour-long

tutorial session, and one three-hour laboratory session each week of the semester. It is expected that all students would attend all lectures. Each student is expected to attend one of 5 parallel laboratory streams which run once a day on each day of the week.

## Research Design

In the project, a design-based research (DBR) approach with practitioner-led cyclical processes of planning, design, and implementation (Collins, Joseph, & Bielaczyc, 2004) was adopted to develop, trial and evaluate the flipped class approach. Five cycles of the flipped class approach were progressively implemented with increasing refinements made to enhancing the course design, materials, and assessment based on the results of the previous cycle. An initial trial of flipping the course for three weeks commenced in the first semester in 2015 (2015A), followed by a fully flipped course in the summer semester that year (2015T) and subsequently in 2016A, 2016T and 2017A (see Table 1 for a summary of the teaching-learning components and activities implemented in each flipped class cycle). (Note: ‘A’ semesters are 12-weeks long with enrolments of about 150 students while ‘T’ semesters are smaller classes with about 30 students are shorter, more compressed and six-weeks long).

Cycles of flipped class intervention	Components of the flipped class design
Cycle 1: Semester 2015A – trialled 3 weeks of flipped class learning	<ol style="list-style-type: none"> <li>Lecturer 1 developed 3 weeks’ worth of instructional videos</li> <li>Created new student problem-solving activities for students to apply concepts introduced in the videos</li> <li>Course Moodle site revised from previous year’s with access to the instructional videos and online tutorial support system</li> </ol>
Cycle 2: Semester 2015T – Fully flipped course design across the semester	Building on the initial cycle: <ol style="list-style-type: none"> <li>Lecturer 1 completed developing instructional videos for his analog electronics section taught in the first half of the course</li> <li>Lecturer 2 made available previously recorded hour-long Panopto screencast videos of his face-to-face lectures focused on digital electronics in the second half of the course</li> <li>Revised and added to the collaborative problem-solving activities</li> <li>Introduced continuous assessment where students were assessed on a fortnightly (for A semesters) /weekly basis (for T semesters) from this cycle on.</li> </ol>
Cycle 3: Semester 2016A – Fully flipped course design	Building on the previous cycles: <ol style="list-style-type: none"> <li>Lecturer 2 revised his videos and created purpose-made videos using PowerPoint and add-on software with quizzes built into the videos to check student understanding</li> <li>Monitored video analytics and student access &amp; usage logs in Moodle</li> <li>Increased support for student learning through setting up drop-in sessions, Moodle Question and Answer forum</li> </ol>
Cycle 4: Semester 2016T	Building on the previous cycles: <ol style="list-style-type: none"> <li>Lecturers established consequences for students who had not watched that week’s required videos. Students were only allowed into a lab session after they had watched a majority of the required videos.</li> </ol>
Cycle 5: Semester 2017A	Building on the previous cycles: <ol style="list-style-type: none"> <li>Lecturers started each week by overviewing key concepts/theory to be covered and how they linked to the instructional videos, practical lab work and problem-solving activities, and, online tutorial system.</li> </ol>

**Table 1.** Summary of the iterative design-based approach to developing the flipped class

### Components of the flipped class

**Lecturer Purpose-made Instructional Videos.** In our flipped class approach, the course weekly lectures were replaced with a suite of short lecturer-developed “Khan-Academy-style” videos (Khan Academy, 2015) lasting between four to 13 minutes long. The instructional videos developed by Lecturer 1 initially targeted the teaching of TCs in the analog section of the course. These had to be specially developed as TCs are rarely addressed in the publically-available online materials. In subsequent cycles, Lecturer 1 opted to use a *Lightboard* to replicate the way he typically teaches in his face-to-face class. In place of lectures, Lecturer 2 initially made available prior recorded screencast lectures of his face-to-face sessions (recorded using Panopto). In subsequent cycles, he developed his own instructional videos using PowerPoint and PowerPoint add-ons. The instructional videos were created with

careful reference to recommendations from cognitive principles shown to be effective in multimedia learning (Sorden, 2005). Completed videos were then uploaded into the Panopto software and linked into the course Moodle site (Moodle is our university online learning management system).

**Continuous Assessment.** Traditionally in the course, students were assessed through two quizzes and a final exam in the first cycle. From the second cycle of the flipped class (see Table 1) onwards students were assessed continuously either biweekly or weekly.

**Problem-solving Activities.** From the onset of the study, the lecturers created problems relevant to particular weeks' videos and the practical lab work. These were added to and refined during the different cycles of flipped class intervention (see Table 1). During the face-to-face in-class (lab) time, students worked in pairs (dyads) or in groups of four to solve these problems, with lecturers and tutors at hand to help. In all cycles, lecturers devoted some of the lab time to 10–15-minute mini-lectures to address students' questions posted on Moodle or related to test results.

## **Data Collection and Analysis**

In each cycle, data were collected through multiple sources: (1) lecturer informal interviews and student focus group interviews, (2) student surveys, (3) class observations, (5) video analytics, (6) student access and online usage logs in the university learning management system (Moodle), and, (7) student achievement data. The analysis focused on examining the impact of the intervention by tracking changes in lecturer pedagogy and student learning. Statistical analysis was conducted on the quantitative data to show differences and trends in student achievement. Qualitative data was analysed using thematic analysis to develop themes through inductive reasoning (Braun & Clarke, 2006). The research project received formal university-level human research ethics approval.

## **Findings**

The following findings are reported according to the quantitative findings followed by qualitative findings to highlight key emerging themes observed across the flipped class cycles on the value of the flipped class approach to student learning.

### **Student achievement**

A significant improvement was noted in students' learning from the initial flipped class cycle to the subsequent cycles especially in the analog electronics part of the course where TC concepts were covered. Data in 2013A and 2014A prior to the study served as a baseline comparison. The average student achievement in the analog part of the course increased significantly in 2015T, 2016A, 2016T, and 2017A when compared to the average achievement in the analog part of the final exam in 2013A and 2014A when the course was not flipped  $F(6, 687) = 32.677, p < 0.001$ . The 2015T semester was a landmark semester where it was the first time the course incorporated a fully flipped class design in combination with continuous assessment. These improved students learning of TCs in the traditionally more challenging analog section of the course.

### **Student perspectives on the benefits and value of the flipped class in supporting learning**

#### ***Value of the Instructional Videos***

Overall, more than 70% of students across all cycles found the videos useful to their learning. Almost 75% of the 2015A students found watching the lecturers' purpose-made videos useful to their learning. As was the case with 2015A and 2015T, the majority of 2016A students reported that both lecturers' videos were useful for their learning (77% and 87% respectively) while another 83% and 75% of students felt that the videos helped them learn the TCs in the course. This was mirrored in the 2016T semester findings with 81% and 70% of students affirming both lecturers' videos to be useful to their learning. However, only about a third of students (32% in 2015A & 30% in 2015T) felt that they learnt equally well from videos and from face-to-face lectures. Others preferred face-to-face lectures or had no preference

The 2015A students also thought that easy access to videos (97%), learning in their own time (90%), and at their own pace (84%) were the three most valued characteristics of the video-based learning during the flipped weeks. About half of students (48%) felt that ideas in videos were well-matched to flipped activities, and around 60% of students felt that videos provided a good overview of a topic and that it was easy to review ideas (62%) through the videos. The majority of students felt that videos helped with lab activities (54%). Only about a quarter of students felt that there was too much information in the videos while 70% felt that videos were well-targeted at their level of understanding; 69% of students said that videos helped them understand key concepts.

Student focus group data corroborated results from the surveys. Across all cycles, students liked learning from the videos because “watching them was a lot easier to understand than being in a lecture” (student quote). Some students said that watching videos helped them concentrate more. Students also liked that they could go back and review videos such as illustrated below:

*You can stop the lecture and you can replay it if you didn't get the lecture the first time. It was probably the best part of the course that you can re-watch it again.*

However, many students mentioned about the challenge of having enough time for video watching:

*Keeping on top of them (watching videos) was the hard bit; it puts more pressure or more dependence on a student for their own learning.*

### ***Value of the in-class (lab) problem-solving activities and interactions with peers and lecturers***

In 2016A, the majority of students (72%) found the group problem-solving discussions in the lab useful for their learning. In focus groups, students mentioned they valued problem-solving activities because these required them to “use the correct vocabulary” which fostered their being able to “explain something that they understood to others”. Some students commented that, as a consequence of these group discussions, they “talked to their lab partner a lot more than they would have otherwise”.

In focus groups, students highlighted that working with a partner was mostly a good experience. This however was dependent on the extent their lab partner had watched the instructional videos and contributed to the discussions around the problems given. One student described the value of such discussions:

*In my case, if we were a bit confused about something we would talk it over and then if I thought that I maybe like had a handle on it then I would explain my thoughts to him [lab partner] and he would think it over and go ‘oh yeah that makes sense’ or if there was a flaw in my thinking he’d point that out.*

In addition to peer interactions, students highlighted the value of the in-lab mini-lectures that lecturers provided on a needs basis when they felt most students were still struggling with a concept:

*I really like the lectures that are held in the labs so we can go through worksheets and then we can get explanation of what to do on the whiteboard and the lecturers are there so we can just talk to them directly.*

### ***Value of a coherent pedagogical and assessment flipped class design***

In the initial cycle of the flipped class design (2015A), students felt that the content of the lecturer videos needed to be better synchronised with the questions in the problem-solving activities and lab work. Similarly, the online tutorials needed to complement the videos as did weekly problem-solving sessions and in-lab mini-lectures:

*The point is you try to do the tutorials and you find that you get stuck on the tutorials because the lecture material doesn't quite match what's in the tutorial.*

Some of these problems were remedied in the subsequent cycles as exemplified through a higher proportion (80%) of 2015T students than 2015A students (54%) reporting that the videos helped them complete their lab work. Student satisfaction with the course increased as a result as reported in this illustrative quote:

*The best way for me to learn was to watch the course material first, do the course material, go to the lab, do the lab, and then if you've got time you go back and you review some of that earlier material in the light of what you've done in the lab and then you understand it.*

Continuous assessment became an important feature of the flipped class design over time. About half of the 2016A students (51%) felt that fortnightly assessments helped them learn “very much”, 42% said that they “somewhat helped”, and seven students said that they “did not help” at all. Similarly, in 2016T, 100% of students felt that weekly assessments helped them learn to a certain degree. The students felt that continuous assessment “kept them on their toes” and forced them to study and learn in small chunks instead of leaving it to the end of

semester. These small chunks made it much easier to stay focused and ensured that students maintained and improved understanding of the course material.

Overall, our findings indicate that student preference for the flipped class approach increased with refinements to subsequent cycles. Student survey data highlighted that in 2015A, only 20% of students said they preferred the flipped class approach as compared to traditional lectures, while in 2016A, 47% of students reported they preferred or strongly preferred the flipped approach, and in 2016T, 67% of students preferred or strongly preferred the flipped approach. In focus groups, students reported the key value of the flipped class approach was “a more flexible self-driven learning compared to traditional lectures”.

## Discussion and conclusion

In our study we integrated a TC-based curriculum with a flipped class approach of teaching and learning in an engineering course to investigate its impact and whether it can facilitate student learning. It is novel as no other studies we know of have attempted to do this in engineering education. Students in our fully flipped class drew from a variety of teaching, learning and assessment resources refined through iterative cycles in the course - pre-recorded instructional videos, online tutorials, posting questions on Moodle, experienced continuous assessment, in-class mini lectures, pair/group problem-solving practices, and practical lab work. Findings indicate that students learning of TCs covered in the analog section of the course was enhanced and that the variety of flipped class activities helped their learning.

Several implications for practice are raised from this study.

Firstly, although valuable, the instructional videos on their own are inadequate for supporting student learning. In our study when students did watch the videos, they find them to be useful to their learning however a majority of students complained about the lack of time/challenges time management. Given the freedom to watch videos in their own time many first-year students lacked the self-discipline and procrastinated, at times coming to labs unprepared to participate in the group problem solving and hands-on activities. This led to the inclusion of more diverse supports (online forums, drop in sessions), reminders for video watching with specific mention of how these linked to each week’s content including monitoring analytics and usage logs, and establishing consequences for failing to watch videos (see Table 1) in subsequent cycles.

Secondly, our study underscores the requirement for a coherent course design and more explicit connections between course elements to allow students to participate in a variety of meaningful ways to enhance their understanding and application of ideas. Students’ satisfaction and achievement enhanced when more effort was made in linking and making clear the ways each course component complemented their learning. A key component was also the introduction of continuous assessment from the second cycle of the study. By especially incorporating continuous assessment to encourage prior class preparation and by making more explicit the connection between the different course elements (online tutorials, videos, weekly tests and practical group work), students are more able to see the relevancy for learning in the course (Kim, Kim, Khera, & Getman, 2014). We recommend that further examination of the effects of the continuous assessment in a fully flipped class may identify additional ways to refine and improve this approach to teaching and learning in the next phase of our project.

In conclusion, as universities continue to explore and adopt e-learning platforms including Web 2.0 and mobile applications to provide for more flexible and innovative student-centred teaching and learning approaches, our study highlights the need for further investigation into the learner perspective to maximize their learning opportunities and outcomes.

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