Evaluating Flipped Classrooms with respect to Threshold Concepts Learning in Undergraduate Engineering

Elaine Khoo, Jonathan Scott, Mira Peter, & Howell Round
University of Waikato
Hamilton, New Zealand

Abstract—**This paper reports on the initial findings from a two year (2015-2016) investigation of the impact of the flipped classroom on student learning of threshold concepts (TCs) in a large introductory undergraduate engineering course at a New Zealand university. As part of the flipped class intervention trialed over a three-week period, a series of short themed video lectures were developed as a replacement for the traditional weekly lectures. The weekly practical lab session were redesigned to incorporate small-group problem solving tasks and assessment. Data from student surveys, interviews, class observations, and video analytics were collected and analyzed. Findings revealed that students were familiar with online videos as a learning resource; they had positive past experiences with using them and were willing to participate in a flipped classroom. However, most students did not watch all assigned weekly videos, including ones crucial to their TC learning. There is indication they thought learning strategies involving interactions with real persons to be more useful to their learning. This suggests that current strategies for motivating students to access and engage with the prepared videos need to be revised to maximize students' learning opportunities.**

Keywords—engineering education; threshold concepts; flipped classrooms; university students; electronics engineering

I. Introduction

This paper reports on the initial findings of a two-year (2015-2016) longitudinal case study exploring whether and to what extent a flipped classroom model of teaching and learning enhances student learning of hard to master threshold concepts (TCs). TCs are concepts students need to master in order to think like a subject specialist [1] and have been evidenced as an effective theoretical framework in facilitating student learning [2].

The flipped classroom is a variant of student-centred learning where lecture materials are assigned as take-home tasks, typically in the form of online videos [3]. By freeing up class time for instructor-student class contact a flipped class provides more flexibility for instructors and students to partake in discussions, collaborative and guided problem solving activities to address student misconceptions, and, is claimed to support the mastery of TCs and the development of the skills needed for 21st century graduates [4]. We postulate that a TC-based flipped-class pedagogical approach to teaching and learning can enhance first year students' learning of TC content in an undergraduate engineering course which had a large enrolment and a strong lab component.

II. Research Context

The "Introduction to Electronics" course is a core undergraduate engineering paper compulsory for EE and ME students. In 2015 approximately 150 students were enrolled in the course and about 30% of the students were from Software Engineering, Computer Science, Education, and other disciplines. The organizational model for this paper 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. The laboratory space is set up for pairs of students to work at one of 18 identical benches, each bench equipped with a PC, oscilloscope, function generator, power supply, soldering iron and DMM (Digital Multimeter).

The Introduction to Electronics class differs from many university classes in its "engineering" style predominance of laboratory learning time. Much of the learning revolves around tacit knowledge and practical skills that are picked up in the lab sessions. Notably the paper differs in having a high level of conceptual difficulty, representing a relatively heavy conceptual load. It is regarded by many students as the most challenging paper of the semester.

Our project team had investigated ways to enhance the pedagogical approach for teaching this course since 2011. In 2011, the course syllabus was rigorously analyzed to identify TCs that it seeks to teach [5, 6, 7] which led to a refinement of the course curriculum and assessment to emphasize student understanding of TCs [8]. In 2013, the face-to-face tutorials were replaced by an online system which was well received by students and credited with an increase in learning [9, 10]. Student achievement data showed that the 2013 student cohort did significantly better than previous cohorts, and students reported liking the flexibility and accessibility of the e-tutorials. This affirmed the value of incorporating online resources in support of student learning in the course. During these changes the cohort was observed extensively and student performance was carefully benchmarked.

A problem inherent in the lecture-plus-lab model is what we term "the phase problem". Typically, students attend lectures spread throughout the week. All students also attend one (out of five parallel) lab streams during the week. Some students have their lab on Mondays—the last group of students has it on Fridays. This means that the theoretical material is covered in lectures from 3 up to 11 days before a student may put it into practice in a corresponding lab (i.e., Friday group). This delay is undesirable. We realized that this delay could be eliminated if the material presented in lectures was made available through instructional videos. The question that arises is: Would the same flexibility and availability that enhanced e-tutorials be as welcomed and as effective in the case of making the instructional materials available in video format?

Currently in 2015, we are trialing a flipped-classroom model for 3-weeks (Weeks 2 to 4 out of the 12-week semester) by replacing the three 50-minute weekly lectures with a suite of short videos which are accessible from the course Moodle website (Moodle is our university online learning management system). The videos, each between 4 to 13 minutes long were created with careful reference to recommendations from cognitive models shown to be effective in online learning [11] and strongly resembled the style found in Sal Khan's work on khanacademy.org. We anticipated that the video materials would allow students more flexibility in viewing and reviewing the course material before the lab sessions in which the learning would be put into practice. The three-hour laboratory sessions were extended to four hours to allow for small-group problem solving activities and more personal interaction with the instructor and demonstrators.

III. DATA COLLECTION AND ANALYSIS

In the project, a design-based research approach [12] with practitioner-led cyclical processes of planning, design, and implementation is used to refine the pedagogical tasks. Multiple data are currently collected from: (1) instructor and student interviews, (2) student surveys, (3) class observations, (5) video analytics, (6) student online usage logs, and (7) student achievement data. As data collection is still underway, we will report only on results from the student pre-intervention survey, and, weekly surveys and video analytics of student viewing patterns during the final week of the flipped class (Week 4). Week 4 was selected for analysis because Thevenin's equivalent circuit theorem—a TC known to be especially troublesome for students—was introduced in this week. Students were expected to watch 11 videos (9 created by the instructor and 2 were from YouTube) related to Thevenin's theorem before attending the lab. Of these videos, we identified and analyzed three that were crucial for student learning of this TC. The pre-intervention survey and Week 4 student evaluation of the intervention quantitative data are analyzed using the SPSS software while qualitative data are coded and categorized to identify emerging themes.

IV. FINDINGS

One hundred fifteen students completed the pre-intervention survey. A majority of students (64%) were 18 years old; most were males (90%); 15% were international students, and 17% were second language speakers of English.

As can be seen in Figure 1, when asked about their preferred ('useful' and 'very useful') learning strategies when learning for formal qualifications, students reported asking the teacher as the most frequent option (95%), followed by watching live demonstrations (93%), referring to the laboratory notes (86%), asking their friends (79%), watching Internet-based videos (76%), learning through trial-and-error (74%), and reading Internet-based text (73%). Reading a textbook was the least favoured strategy (59%). It is noteworthy that students prefer learning strategies in which they can interact with a real/live person be it a teacher, demonstrator or a friend.

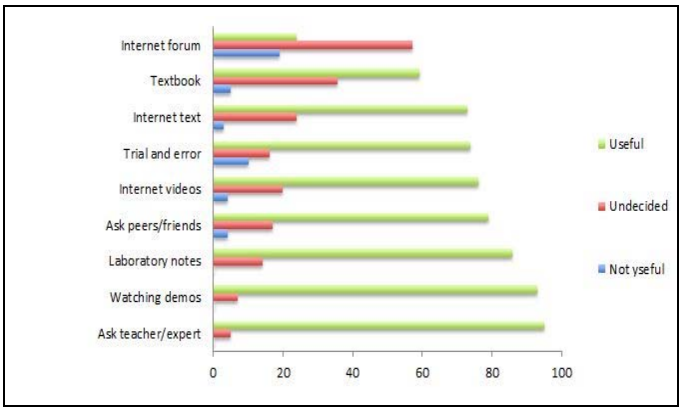

Fig. 1. Strategies students considered when learning for formal qualifications (collated 'useful' and 'very useful')

A majority of students (79%) had used online videos as a learning resource and had positive experiences when using them. Another 14% had also used online videos in the past but did not like the experience. This indicates most of the class are familiar with online videos as a learning resource and had positive experiences with using them.

Most students, 86%, were not familiar with a flipped classroom prior to enrolling in the course, 9% have had some experience with flipped classes, while 3% had only heard about it. Since most students were unaware of the flipped class concept, it was no surprise that when asked if they thought a flipped class could help them learn better in the course,70% were not sure, 17% thought it would, while another 14% did not think so. However, 93% of students were willing to participate in and experience a flipped class. General themes from the open-ended survey question support this broad trend to reveal students generally lacked prior experience with a flipped class (36 responses), were open to the potential a flipped class could offer to enhance learning (16 responses) but were reluctant to lose the structure that regular lectures offered (8 responses), and, a (mis)assumption about losing the human interaction factor found in traditional lectures (6 responses). Some key illustrative quotes include; 'I am new and adapting to the new environment, so I have no relative intention on what it takes to learn', 'Its (Flipped class) very self-directed. If you put in the work it should be very beneficial', 'It kind off becomes me delaying watching the videos till the last minute because I have other assignments to work on', and, 'I believe flipped classwork would result in slightly less success due to the lack of commitment to lectures and inability to ask the lecturer questions'.

During the final week of the flipped class (Week 4), 141 students completed a weekly survey on their learning experiences. Less than half of the class (44%) reported watching a few videos assigned for the week, 39% had watched most, 10% had watched all videos, while 7% did not watch any. Overall, 93% of students had watched the assigned videos albeit to different extents.

A majority of students (74%) thought the length of the videos were just right, 24% thought they were too long while only 3% thought they were too short.

As can be seen in Fig. 2, over half of the students did not watch all of the three key videos related to learning the Thevening theorem (e.g., 61% did not watch 'Finding Thevenin Equivalent Circuit', 54% did not watch 'Thevenin Equivalent Circuit Example'). Interestingly, almost all students (97%) watched the video titled 'Thevenin Equivalent Circuit and Measuring It'. Remarkably, 41% of students watched this video once, almost 30% watched it twice, and 2% of students viewed it up to eight times compared to the other videos.

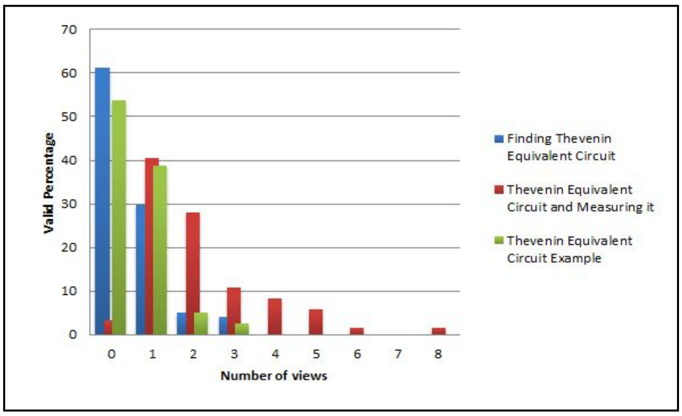

Fig. 2. Student viewing patterns of the three key videos for TC learning in Week 4.

The high student regard for this particular video was corroborated by the fact that over half of students (57%) thought this video to be the most engaging for their learning (Fig. 3). Conversely, the other two key videos associated with TC learning ('Thevenin Car Battery Equivalent Circuit Example' and 'Finding Thevenin Equivalent Circuit of a Network') had less than 40% of the class watching them at least once (Fig. 2) and were rated to be engaging by only 30% and 20% of students respectively (Fig 3).

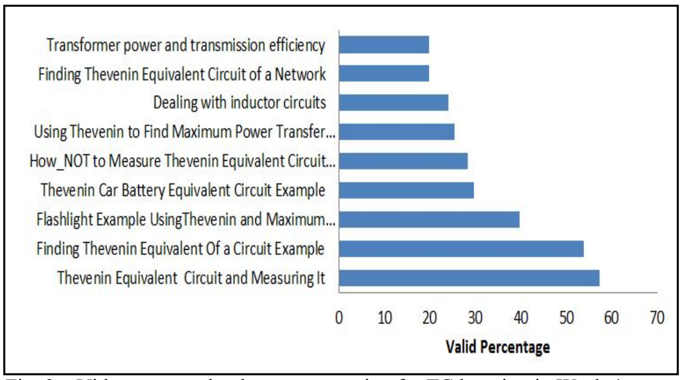

Fig. 3. Videos reported to be most engaging for TC learning in Week 4

Further examining of the characteristics of this "most engaging of the videos" ('Thevenin Equivalent Circuit and Measuring It') revealed it importantly contained footage of practical ideas—making measurements in the lab, which was integrated into a lecture of the theoretical concepts. Students probably found the practical demonstration helped to exemplify the conceptual ideas in a manner that was useful and engaging to their learning which the other videos did not.

When asked about the extent they thought the instructor prepared videos had helped them learn about Thevenin's equivalent circuit, 96% of students reported 'somewhat' or 'very much so', while only 4% thought the videos did not help them learn; this responses included students who did not watch the prescribed videos. This finding suggests that when students watch the videos, almost all of them find them to be helpful to their learning of the TC. Future analysis of the student achievement data may provide further evidence of the effect of (timely) video watching on learning the TC.

V. Discussion and Conclusion

In our study we integrated a TC-based curriculum with a flipped class model of teaching and learning in an engineering course to investigate if and how a TC-inspired flipped class can facilitate student learning. It is novel as no other studies have attempted to integrate a TC-based flipped class approach in engineering education. The results thus far show that students report to prefer learning from a real person (teachers, demonstrators, peers). The video analytics data reveal that students are not fully engaging with the assigned weekly videos. Importantly, when students do watch the videos, they find them to be useful to their learning of the TC.

From past experience, we observed that students generally find learning TCs to be more difficult than non-TCs and we assumed this would still be the case even if the form of course delivery had changed to online videos instead of lectures. The fact that over half of the class did not watch two of the three key videos relevant to TC learning prior to the practical lab session leaves us in doubt as to whether students had understood the TC. This poses a question about when and if students will have a chance to learn the TC. Students' hesitancy/failure to watch the videos (on time), despite their familiarity and past positive experiences with learning from online videos and their being open to the notion of a flipped class, may point to a limitation of a flipped class approach designed for the first semester of a large undergraduate course. We had also foreseen the possible loss of pedagogical responsiveness and group momentum without any scheduled course event that brings the whole class together (such as lectures) as another potential limitation of our intervention. This suggests a need to look into possible revision of current strategies for motivating students to watch the videos and come to the face-to-face class sessions prepared to participate in active learning tasks and ask questions. Another possible way forward is to closely examine the characteristics and content of the instructor prepared videos that students found particularly engaging and useful to their learning to inform our (re)design of future teaching videos.

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 teaching and learning approaches, our study highlights the need for further investigation into the learner perspective to maximize their learning opportunities and outcomes.

REFERENCES

[1] J. Meyer and R. Land, Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge. Oxon, England: Routledge, 2006.

[2] M. Peter and A. Harlow, Re-envisioning tertiary teaching and learning of difficult concepts: How "threshold concepts" afford understanding of problematic ideas. [Available Online] http://www.tlri.org.nz/tlri-research/research-progress/post-school-sector/re-envisioning-tertiary-teaching-and-learning, 2014.

[3] J. F. Strayer, "How learning in an inverted classroom influences cooperation, innovation and task orientation", Learning Environments Research, vol. 15, pp. 171-193, 2012.

[4] R. O'Toole, Pedagogical strategies and technologies for peer assessment in Massively Open Online Courses (MOOCs). Coventry, UK: University of Warwick, 2013.

[5] J. Scott, and A. Harlow, "Identification of threshold concepts involved in early electronics: Some new methods and results", Australasian Journal of Engineering Education, Vol. 18, No. 1, 2012.

[6] J. Scott, A. Harlow, and M. Peter, Towards A TCT-Inspired Electronics Concept Inventory, Proceedings of the National Academy's Sixth Annual Conference and the 4th Biennial Threshold Concepts Conference, Dublin, January 2014, 113-117.

[7] A. Harlow, M. Peter, and J. Scott, Students' Perceptions of Travel Through the Liminal Space: Lessons for Teaching, Proceedings of the National Academy's Sixth Annual Conference and the 4th Biennial Threshold Concepts Conference, Dublin, January 2014, 62-67.

[8] J. Scott, M. Peter, and A. Harlow, ``An Electronics Threshold-Concept Inventory: Assessment in the face of the dependency of concepts", Proceedings of the 1st IEEE Teaching and Learning in Engineering conference (TALE), Hong Kong, 20--23 August, 2012, T1C-2.

[9] M. Peter, A. Harlow, T. Balsom, and J. Scott (2014). Virtual learning: How online tutorials shape learning of threshold concepts. Paper presented at the 5th Biennial International Threshold Concepts Conference: Threshold Concepts in Practice. 9-11 July 2014, Durham, England.

[10] J. Scott, T. Balsom, H. Round, M. Peter, and A Harlow, "Threshold-Concept Inspired eTutorials in Electronics", Proceedings of the 20th Electronics New Zealand Conference, Albany, 5-6 September 2013, pp127--132.

[11] S. D. Sorden, "A cognitive approach to instructional design for multimedia learning" Informing Science: International Journal of an Emerging Transdiscipline, vol 8, pp. 263-279, 2005.

[12] A. Collins, D. Joseph, and K. Bielaczyc, "Design research: Theoretical and methodological issues," The Journal of the Learning Sciences, vol. 13, pp. 15–42, 2004.