Full Paper

Introduction

Marton et al. (2005) and Biggs (1999) argue that students will approach their learning differently depending on the pedagogical models that their lecturers use. Lecturers who rely on one-way communication in lectures and tutorials, and test for declarative knowledge in end-of-course, closed-book exams tend to encourage students to take a surface or passive approach to learning. Those who require their students to interact in lectures and tutorials and problem solving projects, and who test students' deep understanding of the topic via exercises, quizzes and continuous and authentic assessment tasks, help instil a deep or active approach to learning. There are many ways to encourage a deep approach to learning. In a featured article in the International HETL Review in 2014, Estes et al. (2014), summarized and critiqued the practice and research literature that underpins one of them, namely, an emerging pedagogical model called 'the flipped classroom'. In the 2014 AEEE conference the first author presented a first cycle of action research (Lucke, 2014) that studied an example of 'flipping the classroom' in Engineering Education. This paper reports on a second cycle of that research.

Flipped Classrooms

The flipped classroom allows for an instructor to provide traditional, low cognitive level, lecture materials in an alternative format outside the classroom, freeing up class time normally used to 'convey' information to students (Toto & Nguyen, 2009). Instruction that used to occur in class (introducing fundamental concepts) was accessed in advance of class (generally at home), so that students were well prepared and could derive the most benefit from time spent in the face-to-face learning environment (Tucker, 2012). Students worked through specially developed narrated lecture material (eLectures) online each week using our learning management system (LMS), prior to attending the face-to-face class sessions. The face-to-face sessions were then used to foster student engagement by working through typical problems, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities (Toto & Nguyen, 2009; Tucker, 2012). Toto and Nguyen (2009) maintain that flipping lectures retains the best qualities of the traditional teacher-centred lecture model while also including the best qualities of the active learning or student-centred teaching model.

The weekly narrated eLectures allowed students to work through and study the fundamental learning material when and where they wanted, and for as long as they wanted. Different students learn at different rates and this arrangement allowed them to spend as much time learning the fundamental material as the needed. All students need time to be able to absorb and process the information needed before it can be applied (Toto & Nguyen, 2009). In order to encourage students to utilise and engage with the eLectures, a number of graded questions were included as part of the eLecture content. Students submitted their answers to the eLecture questions using a classroom response system. A typical eLecture question is shown in Figure 1.

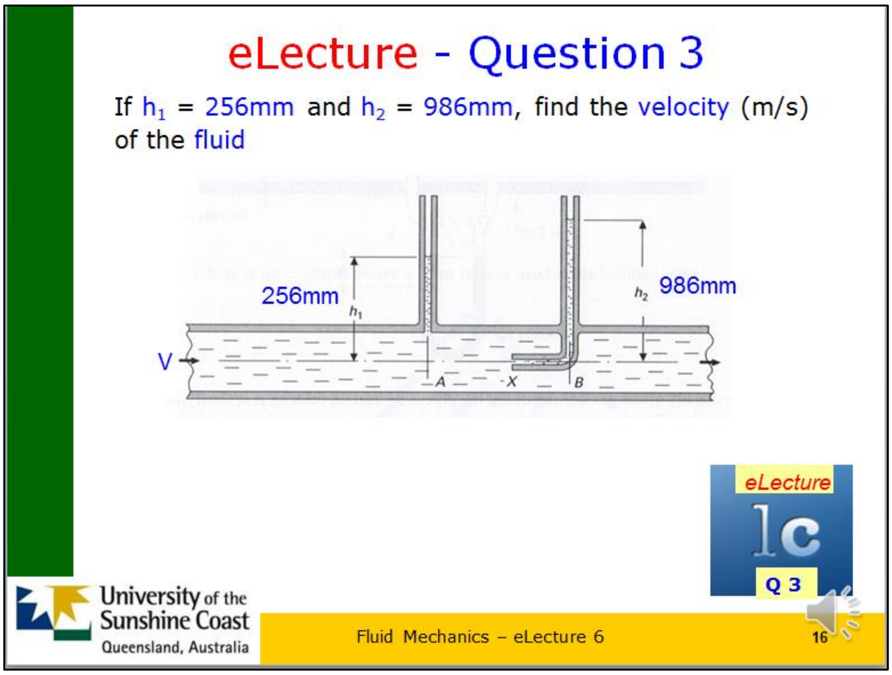


Figure 1: Typical Weekly eLecture Question

Classroom Response Systems

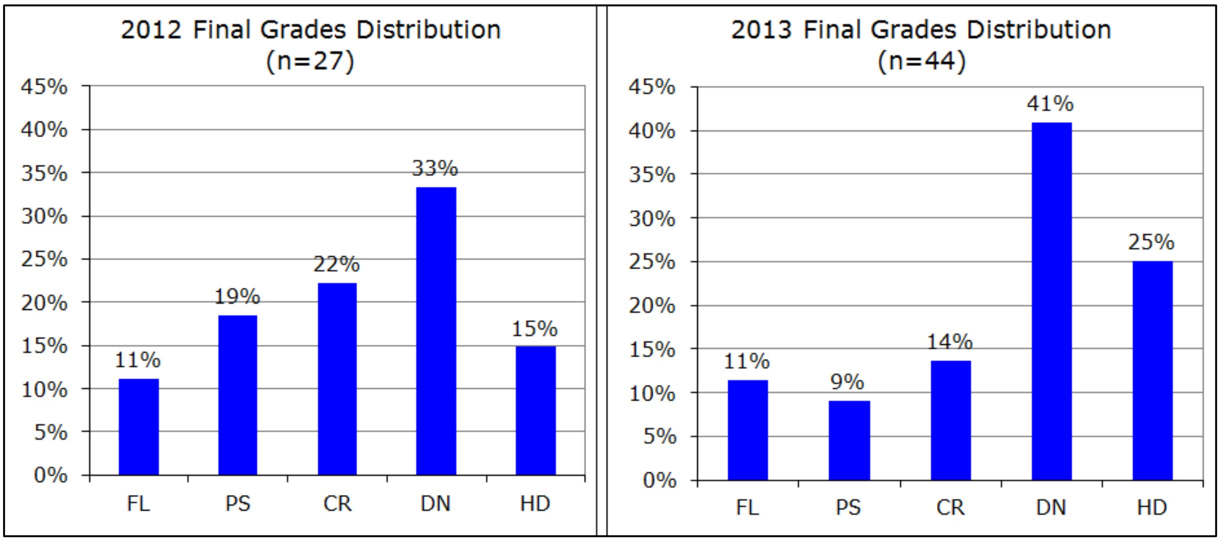
Active learning principles recognise that when students are actively engaged with their learning, they are much more likely to understand the concepts. The more involved and engaged the student is, the greater his or her level of knowledge acquisition and general cognitive development (Smith et al., 2005) and engagement in higher-order thinking tasks such as analysis, synthesis, and evaluation (Bonwell and Eison, 1991). Biggs (2003) maintains that the way to narrow the gap in understanding between students is to involve them in activities that are engaging and require them to use higher-level cognitive processes. Student engagement is critical for student achievement, retention and success (Dunn et al., 2012) and including effective active learning strategies is fundamental to providing a successful engineering education (Toto & Nguyen, 2009)

Classroom Response Systems (CRS) have been shown to make classrooms more engaging for students, improve student participation and interaction, improve cognition and retention, and can even improve grades (Bakrania, 2012; Bartsch & Murphy, 2011; Dunn et al., 2012). The use of CRS allows instructors to provide immediate feedback, particularly in large classes (Dunn et al., 2013). Using a CRS to engage students has advantages over many other methods, such as raising hands, because the interaction is anonymous (Beekes, 2006; Guthrie & Carlin, 2004) and so students do not fear being wrong in front of their peers or the instructor (Wood, 2004). Importantly, this means that the use of a CRS allows instructors to engage students who otherwise remain disengaged, such as students with 'lower class standing' (Trees & Jackson, 2007) or students self-identified as reluctant participators (Graham et al., 2007). Using CRS also allows students to evaluate their own performance.

While CRS has been used for well over a decade and been shown to successfully improve student engagement and participation, cramming CRS into already content-heavy class time does not embrace the potential for CRS to improve student engagement and student learning (Dunn et al, 2012). The effectiveness of CRS depends strongly on the quality and variety of the questions and the use of CRS should be planned as an integral component of the course (Beatty et al. 2006) which enhances and reinforces the learning outcomes. This study examined the effectiveness of using the flipped classroom approach in conjunction with a state-of-the-art CRS over a three year period to improve student engagement, motivation and cognition in a second year engineering Fluid Mechanics course.

Approach

In the first cycle we investigated whether or not the flipped classroom model could improve the motivation and learning outcomes for a group of second year engineering Fluid Mechanics course (n=66). Our data revealed that while students' perception of the effectiveness of using the new teaching format was overwhelmingly positive and students said their motivation had improved, their scores for tasks submitted via a classroom response system (Top Hat - https://tophat.com/), did not match the levels we had expected. It appeared that the increased levels of student engagement did not cause any significant change in overall results (Figure 2).

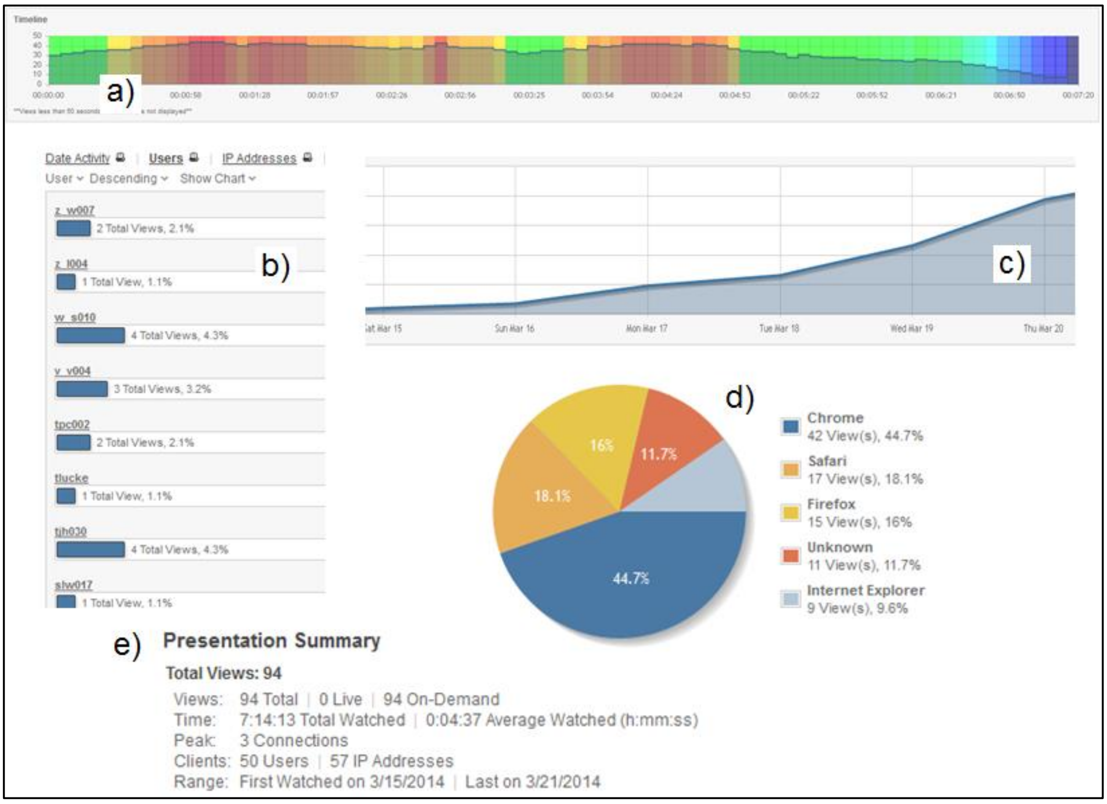


FL=Fail (0-50%); PS=Pass (50-65%); CR=Credit (65-75%); DN=Dist. (75-85%); HD=High Dist. (85-100%)

Figure 2: Comparison of Student Final Grades for years 2012 and 2013

There were a number of reasons why this might be the case, including the correct use of the technology, so a second cycle of research was carried out with the purpose of determining if a subsequent cohort of students (n=62) would also be motivated by the flipped classroom, and if changes to our approach and the correct use of a CRS we had trialled in 2014 (Learning Catalytics - https://learningcatalytics.com/) could also improve their learning outcomes (as demonstrated by better scores).

In order to measure the impact and value of the eLectures in 2014, and to improve the accuracy of the data collection and statistical analysis of students' learning behaviour while working through eLectures, they were recorded and accessed through Mediasite (http://www.sonicfoundry.com/mediasite/). Using Mediasite allowed precise tracking of each student's viewing activity for each eLecture throughout the course. The collected data could be presented using a variety of interactive graphs, intensity maps or playback statistics. Figure 3 shows some of the analytical tools available through Mediasite.



a) Activity Heatmap; b) User Record; c) Activity Timeline; d) Browser Use; e) User Summary

Figure 3: Various Statistical Analysis Presentation Tools Available Through Mediasite

In the third cycle we used learning analytics to investigate how effective the flipped classroom approach was in producing desired student learning outcomes. The study analysed data collected by Mediasite (through the University's LMS) to determine whether there was any correlation between the total amount of time students spent on the weekly eLectures and their results for three of the summative course assessment tasks. The three assessment tasks used in the study to measure student performance were the correctness of their answers to the weekly eLectures and Workshop CRS questions (30% of final grade), and their results in the final exam (40% of final grade).

The data collected through Mediasite were analysed using both linear regression and Pearson product-moment correlation coefficient (PCC) techniques. Although PCC analysis is generally the more widely used way of measuring the degree of linear dependence between two variables, linear regression plots were used here to present the data comparisons in a way that is easier to visualise.

In order to evaluate whether the total amount of time spent on the eLecture materials affected student performance in the final exam, these variables were compared. It was hypothesised that the more time students spent studying the weekly eLecture material, the better their performance would be on their final exams. Unfortunately, Figure 4 shows a poor correlation (R^2 = 0.0617, PCC = 0.2623) between the total time (up to Week 13) students spent studying the eLecture material and the correctness of their final exam questions. These results were unexpected and potentially disappointing with respect to the efficacy of flipped learning. However, further research is needed to investigate this in more detail.

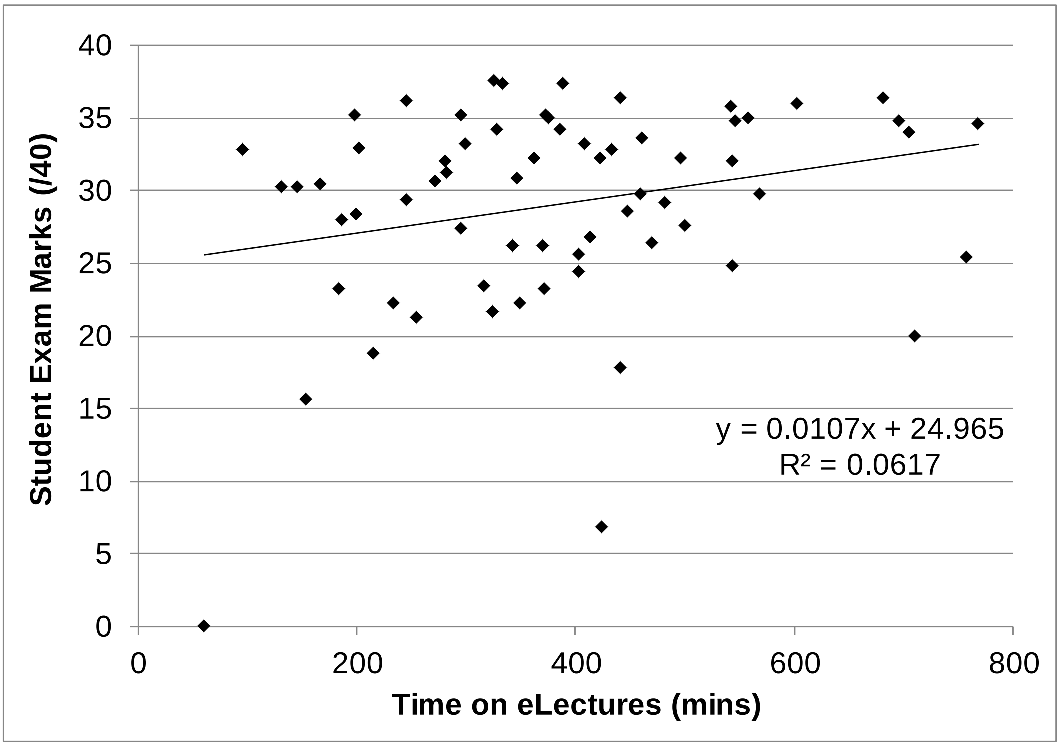


Figure 4 - Comparison of time on eLectures with final exam results (PCC = 0.2623)

Student feedback on the new flipped classroom teaching method was solicited at various times throughout the semester for evaluation purposes. Table 1 lists one of the CRS evaluation questions and the student responses for that question. Table 2 lists a small sample of student responses to one of the open-ended feedback questions asked in the end of semester student course evaluation survey.

Table 2: Student responses (n=64) to one CRS evaluation questions

Question: Do you like or do you not like being able to work through the eLecture material whenever it suits you?	
I like it a lot!	78%
I like it a little!	20%
I dislike it a lot!	2%
I dislike it a little!	0%

Table 3: Sample of end of semester, open-ended student evaluation question responses

Q3.1) Aspects which were done well and which should be continued
I really enjoyed the LC part of the course. It enabled me to go ahead and review the lecture content more than once to help reinforce what was being taught. And each week's lectures gave a good foundation to the workshops where that knowledge could then be expanded upon.
LC was a great method of learning at your own pace at home. It also makes you learn the course content each week, and then by applying it the next day it cements the knowledge learnt.
Really enjoyed the eLectures and online assessments... They really helped me gain a full understanding of subject material

The short online lectures (eLectures) each week were very beneficial and I found them to be much more useful then a standard lecture.
The way the course was delivered was excellent. I particularly liked the eLectures and subsequent question format, which I think really helped me understand fluid mechanics.
eLectures are very helpful and an excellent way of learning the material (It is not possible to pause or rewind an actual lecture).
The whole course outline was perfect. This is the way i would like all my subjects to be taught. No more boring lecture, finally a way that keeps my engaged and wanting to learn. Really enjoyed the working style wouldn't change a thing.

Discussion

A previous study (Lucke, 2014) of an action research intervention, in which we introduced the flipped classroom approach to a second year fluid mechanics class, did not show conclusively that it was any more successful than using a traditional teaching approach. Although students spent time working through the weekly eLecture material, there was a relatively poor correlation between time spent on eLectures and their assessment grades. A second cycle of research (2015) was implemented to determine if the poor results may have been the result of students rushing through the eLecture material and accompanying questions so that they did not miss out on marks and come up to speed with the material before the lecture. In this second cycle we sought to assemble evidence to confirm this hypothesis and to determine if the flipped classroom can only be more effective than traditional teaching practices if students work through, learn and understand the pre-lecture material properly. The other part of our research question was to confirm the earlier finding from cycle one that indicated that students were overwhelmingly positive about the new format. In the post survey for the second and third cycles, the new cohorts reiterated the sentiment expressed in cycle one, namely that they enjoyed and embraced the new teaching and learning approach. The other aspect of this study was to determine if the correct use of a new CRS proved to be a useful tool to monitor and predict student performance and learning.

Generally, student feedback on the flipped learning method was overwhelmingly positive and Tables 1 and 2 clearly demonstrate how much students enjoyed the new teaching and learning approach. However, as discussed above, while it was evident that students successfully embraced and engaged with the flipped learning approach, this did not appear to translate into significant improvements in student cognition, or produce the deeper learning outcomes described by Marton & Säljö (1976). Although the final student grades for the following cohorts were slightly higher than previous years, there was no real evidence that this was directly due to the use of the flipped classroom approach. Students often worked together in groups (Figure 5) to solve questions and it was suggested that this probably increased the collective average student grades. New ways to measure the success of the flipped learning approach are being planned for future studies.

The benefits of our ongoing research project include the following: increased evidence for a pedagogical model that can raise motivation among Engineering students; increased motivation among lecturers who use eLectures as home work and spend their lecture time addressing problems that students have with content knowledge; providing just-in-time assistance to weaker students so that their studies become less frustrating and their understanding of the topic is deepened; the development of graduate attributes, such as communication skills and academic independence among students; and, graduates who are capable of adapting to the demands of rapidly changing industrial circumstances because they have learned to be problem solvers and innovators.

Figure 5: Students Teams Engaged with Workshop Activities

Conclusion

This study used learning analytics to investigate whether the flipped classroom approach used in a second year fluid mechanics class was any more successful than using a traditional teaching approach. It was hypothesised that the more time students spent working through the weekly eLecture material, the better their responses would be to the weekly CRS questions. However, the study found a relatively poor correlation between these two variables and the correlations between eLecture time and final exam mark were equally low. The study found no real evidence to suggest that learning outcomes of the flipped classroom approach were any better than traditional quality teaching methods.

On the plus side, student feedback on the flipped classroom method was overwhelmingly positive and clearly demonstrated that students enjoyed and embraced the new teaching and learning approach. However, this did not appear to translate into significant improvements in student cognition or deeper learning.

Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the Flipped Classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor and predict student performance and learning. While this initial study has produced some interesting and thought-provoking results, it must be recognised that these results must be viewed in their proper context. There can be many factors that influence performance and results from one student cohort to the next and these would have to be taken into account to enable more accurate conclusions.

The study is continuing and further refinement of the research methodology is currently being planned. It is hoped that the future changes will provide a clearer indication of the real benefits of flipped learning to students and enable a tangible evaluation, assessment and comparison of student learning outcomes.

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