INVESTIGATING THE EFFICACY OF FLIPPED LEARNING TO PROMOTE STUDENT ENGAGEMENT AND ACHIEVEMENT

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ABSTRACT

The use of pre-lecture resources, including key content videos and mastery quizzes, to promote student engagement with a second year chemistry course has been investigated. Students' accessing and completion of the pre-lecture materials remained high throughout the semester. The average view count per student for the videos ranged from 1.2 to 1.8 times per week, depending on the complexity of the material. The median attempt counts for the weekly quizzes followed the trend of the view count, ranging between 2 and 6 attempts over the 10 weeks that specific pre-lecture resources were available. Student perceptions of the partially flipped approach were approximately equally split between favouring traditional and flipped approaches at the beginning of the semester. They were particularly supportive of a more active approach to lectures with worksheets and access to lecturers for questions.

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INTRODUCTION

Reduction in cognitive load through the use of pre-lecture resources can improve student performance (Sirhan, Gray, Johnstone & Reid, 1999). These pre-lecture resources do not need to be delivered in person, therefore they present an opportunity for technology to support student learning. When used in a lecture course that blends online and face-to-face teaching, cognitive load in the face-to-face portion can be reduced by introducing students to key terms and concepts prior to the lecture (Sirhan & Reid, 2001). Lecturers can then spend additional time focused on active student learning as they are able to reduce some of the material that is delivered in class. Several studies have shown that active learning increases student engagement and academic achievement (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt & Wenderoth, 2014; Haak, HilleRisLambers, Pitre & Freeman, 2011; Michael, 2006). Flipped and partially flipped learning may be a solution to improving student learning outcomes. Flipped learning here refers to a teaching approach where course material is not delivered in lectures. Instead, content is delivered before classes, often through audio-visual presentations, and face-to-face time is focused on active problem solving. Partially flipped learning in this case refers to a partial adoption of the flipped approach, and some content delivered prior to lectures, with lecture time divided between content delivery and active problem solving.

A number of studies have shown clear benefits of flipped courses at the university level in chemistry, including reduced student failure rates (Fautch, 2015; Flynn, 2015; Hibbard, Sung & Wells, 2016). Seery and Donelly (2012) implemented 10 online pre-lecture modules including on-screen text with overlaid audio, followed by a short quiz to check understanding, with improved student performance. However, success of such programs can be dependent on aspects such as lecturer dedication to the flipped course (Weaver & Sturtevant, 2015) and student commitment (Ryan & Reid, 2016).

University students in their second year of study often experience a drop in engagement and academic achievement (Graunke & Woolsey, 2005; Loughlin, Gregory, Harrison & Lodge, 2013). At the University of Sydney, a project was developed in 2016 to improve the learning outcomes of second-year chemistry and physics students.

The aim of this study is to investigate the efficacy of the project in using partially flipped learning as an intervention to improve participation and achievement in second year chemistry. Failure rates for previous second-year chemistry cohorts have been high, with student disengagement perceived to be a likely cause. Specific research questions are focused on whether pre-lecture video material and quizzes increase engagement with face-to-face classes. In addition, whether any enhanced engagement leads to improved subject matter understanding and therefore increased motivation and improved academic achievement, both on an individual basis as well as over the whole cohort.

METHODS

Students at the University of Sydney studying a second year core chemistry course at the mainstream, advanced or special studies program level were the study participants. The course was partially-flipped. Videos of approximately 10 minutes duration focused on the upcoming week's content were viewed by the students, followed by a short quiz due by Wednesday each week. The videos presented key concepts for that week using simple visuals from prepared lecture slides. An audio track accompanied the video, spoken by one of the lecturers for that topic. Material covered was from organic and quantum chemistry as shown in Table 1. The videos were uploaded to YouTube each week, and were therefore able to be paused and rewound, to be watched at the student's pace.

The students completed a follow-up online quiz with 10 multiple-choice questions, most of which included similar images to those in the video. The questions were written by the lecturers and targeted the key concepts from the video. Each of the 10 questions had multiple versions, which were randomly drawn for inclusion in a student quiz when it was generated. These mastery quizzes were each worth 1 mark towards the final semester grade, in order to encourage engagement and completion. The videos and quizzes were accessible through a website link, which passively recorded data as outlined below. The active learning, in-class techniques have previously been incorporated into first year classes at the University of Sydney (Badiola, Bartimote-Aufflick, Bridgeman, George, Hudson, Neto & Schmid 2013; Bridgeman & George 2014) and have evolved from the 'Process Oriented Guided Inquiry Learning' (POGIL) approach (Moog & Spencer 2008) widely used in North America with adaptations to suit the Australian context.

Table 1: Lengths and Topics of Weekly Pre-Lecture Videos

Week	Video Title	Length	Area
2	Energy Profile Diagrams	9:17	Organic
3	Conformational Analysis	9:32	Organic
4	Carbocations	9:12	Organic
6	Directing Effects in S_EAr Reactions	10:14	Organic
7	The Mighty Carbonyl	10:16	Organic
8	Enols and Enolates	10:20	Organic
9	The Aldol Reaction	10:05	Organic
11	Electromagnetism and Spectroscopy	7:17	Quantum
12	Local Modes and Group Frequencies	7:26	Quantum
13	Vibronic Transitions	7:41	Quantum

The lectures were organised in two streams at 8 am and 12 pm on Monday, Tuesday and Thursday. Students were allocated to one or the other by the central timetabling system, and both streams of core chemistry included mainstream, advanced and special studies level students. The 8 am stream had Lecturer A for weeks 1-9, followed by Lecturer B for weeks 10-13. The 12 pm stream had Lecturer C for weeks 1-5, Lecturer D for weeks 6-9, and Lecturer E for weeks 10-13. Lecturers A and B created the videos and quizzes for the partially-flipped section of the course. The assessment components were the 10 weekly pre-lecture quizzes (each worth 1%), in-semester tests in weeks 6 and 10 (worth 5% each), the final exam (worth 55%) and a laboratory component worth 25%.

The study had four main sources of data. The first was two surveys. These were conducted with the second year core chemistry students during the semester in weeks 5 and 13. The second was the week-by-week lecture attendance for weeks 3–13. The third data source was passively collected information on the students' engagement with the pre-lecture resources including videos and quizzes. The final data source was the 2015 and 2016 academic results for the course.

The full cohort of students (n = 281) were given surveys during laboratory time in week 5 of semester. Return of the survey was taken as consent to participate in the study, with 170 students electing to participate (97 M, 69 F, 4 gender not supplied). The students' expectations with regard to flipped learning and level of in-class active participation were determined. Of the students that returned the survey, 99 were studying chemistry at the mainstream level, 51 were studying at the advanced level, and 18 were in the special studies program (2 course not supplied). The same full cohort was surveyed again during tutorials during week 13 of semester, with 149 students electing to participate. The students were asked about their perceptions regarding the pre-lecture videos and quizzes.

In addition, data on engagement with the videos and quizzes were passively collected for the entire cohort. The data were collected into a database through the same system that students accessed the quizzes through. Items recorded were the times that students clicked the video links, whether students answered questions correctly, which questions were being attempted, and the time taken per question. Overall data included the number of video views, number of quiz attempts and quiz scores, as well as time taken to complete the quiz. These data were analysed to determine general trends in the approach to the pre-lecture resources.

RESULTS AND DISCUSSION

WEEKLY VIDEO AND QUIZ ENGAGEMENT

The majority of students watched each weekly video (Table 2), with the average watching count between 1.15 to 1.79 views per student attempting the quiz. This may be interpreted as an indication that most students perceived the videos to be necessary to understand the material. In addition, it appears in this interpretation that one or two focused views were sufficient for mastery of the pre-lecture foundation concepts. The average views per student varied somewhat over the weeks, which was a possible indicator of the difficulty or unfamiliarity of the key concepts covered. Increased assessment load in other subjects, or other external factors, may have contributed to the variability in the number of students watching. Further data from surveys and planned interviews may be able to clarify the student perceptions of the videos.

Table 2: Video viewing data

Week	Total Views	Average Views	Students Watching
2	391	1.62	90%
3	411	1.62	88%
4	364	1.44	89%
6	456	1.79	91%
7	332	1.42	85%
8	331	1.48	84%
9	328	1.45	83%
11	284	1.15	76%
12	282	1.22	83%
13	302	1.40	82%

The final quiz mark for students in each week was close to the maximum, with an unlimited number of quiz attempts allowed whilst the quiz was open for completion. The average final mark ranged from 9.7–10/10. Although the final mark remained consistent, the number of attempts per student varied over 10 the weeks, as seen in Table 3. An increase in median attempts in a given week may indicate increased content difficulty. The week 6 quiz and video, "Directing Effects in S$_E$Ar Reactions" had the highest median attempt count and highest total attempt count, and the highest average video views of students completing the quiz. Watching of the video is interpreted as an attempt to understand the content, thus a higher percentage of students watching the video, and an increase in average views, can be taken to indicate greater content difficulty in a given week. Alternatively, a particularly high number of attempts may indicate that a student was taking less time to master the concepts, instead re-attempting the quiz multiple times without pausing to understand the material.

Table 3: Quiz attempts each week over the cohort

Week	Average Score	Total Attempts	Median Attempts	Maximum Attempts
2	10	729	2	19
3	9.9	1866	5	37
4	9.9	1362	4	23
6	9.7	2351	6	79
7	9.8	1305	4	37
8	9.8	1427	4	39
9	9.8	1641	5	52
11	9.9	870	2	28
12	9.9	1824	5	41
13	9.8	1616	4	77

Over the semester, there was some variation in the number of students attempting the quiz. In the first 4 quizzes of the course 242-255 students completed the quiz each week. There was a small decline in weeks 7-9 to 224-233 students. There was an increase at the same time as the major topic change from organic to quantum chemistry in week 11; numbers again decreased in the final two weeks (Figure 1).

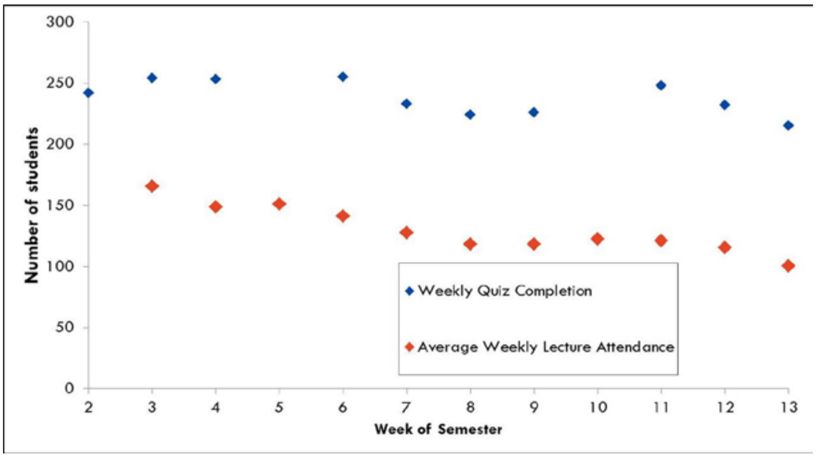

Figure 1: Number of students completing pre-lecture quiz and attending lectures each week

More than 75% of the cohort (minimum 215/281 students) completed the quizzes each week. Attendance at lectures was unfortunately not as high, as seen in Figure 1. Average weekly attendance was calculated as the average attendance per day (summing the 8 am and 12 pm lectures), over 3 lectures per week. A small increase in attendance occurred with the major topic change from organic to quantum chemistry at the end of week 9. The pattern of lecture attendance shows final week student numbers representing 35% of the total cohort.

STUDENTS' LEARNING PREFERENCES

The students who returned the first survey (n=170) indicated, on average, an intent to attend 2.54 lectures per week. Initial opinions from the students surveyed indicated that approximately 40% (71/170) expected to spend most of their time learning from the lecturer. Approximately 45% of the students (78/170) expected to spend most of their time learning on their own, with the remainder expecting a mix of the two, as well as learning from their classmates. There is evidently a split between those students who are lecturer-focused and students who are more self-directed learners. The students choosing to spend most time trying out questions for themselves may also have external commitments that they prioritise over attending lectures.

The students were also surveyed regarding their initial preference for flipped or traditional learning. The results are shown in Table 4, demonstrating a slight preference across the cohort for traditional learning (defined as “First seeing content in lectures; lecturers talking while I write notes”) over flipped learning (defined as “Watching videos before lectures; completing worksheets and having discussions in class”) with a significant minority having no preference between the two.

Table 4: Student learning style preference by chemistry level

Style Preference (%)	Flipped	Neither	Traditional	Total
Advanced	10.0	7.6	12.4	30.0
Course not supplied	0.0	0.6	0.6	1.2
Mainstream	23.5	12.4	22.4	58.2
SSP	1.8	4.1	4.7	10.6
Total	**35.3**	**24.7**	**40.0**	**100**

The first survey also asked students for their general opinion on the most important thing that would encourage them to attend lectures. A selection of representative responses follows:

- Interactive worksheet based learning integrated into lectures
- Engaging, interactive content and opportunities to ask questions
- Explaining concepts with relevant examples

From these responses it is clear that students have a preference for active learning and see the lectures as a chance to engage with lecturers as subject matter experts. In particular, many students saw the in-lecture worksheets as an opportunity to test their knowledge and answer questions.

In the final teaching week of the course, the students were again surveyed on their opinions on flipped versus traditional instruction. On the five point Likert item "I prefer flipped learning over traditional learning", 48 indicated agreement or strong agreement, 35 indicated disagreement or strong disagreement, and 61 indicated a neutral response (5 students elected not to answer). In addition, the second survey asked students about their overall experience with the videos and quizzes. Typical responses included the following:

- It made me more prepared for the content covered in lectures
- The quizzes showed us what I didn't understand immediately, they helped to clear up some concepts in our own time. I could check if I had gained the correct information from the video.
- Even when I felt busy, I felt motivated to make the time to watch the video and do the quiz

The students noted that it would be beneficial to have the quizzes earlier in the week, and that they would like questions posed in the video in a more interactive style. From the responses, the partially-flipped approach appears to be improving students' engagement with the course. Most students said that the pre-lecture videos and quizzes improved their learning.

STUDENT ACHIEVEMENT

Student academic achievement for the 2016 course (281 students) was compared with the 2015 results (240 students). The average final theory mark increased from 41.25 to 46.19 out of 75 in 2016. Increases were seen in the final exam and the in-semester tests, confirming that the overall mark increase is not due to the additional marks available from the pre-lecture quizzes only. Final student letter grades showed an increase in High Distinctions (HD) and Distinctions (DI), a stable number of Credits (CR), and decreases in Pass (PS) and Fail (FA) grades (Figure 2). Overall passing percentage increased from 75% to 82%.

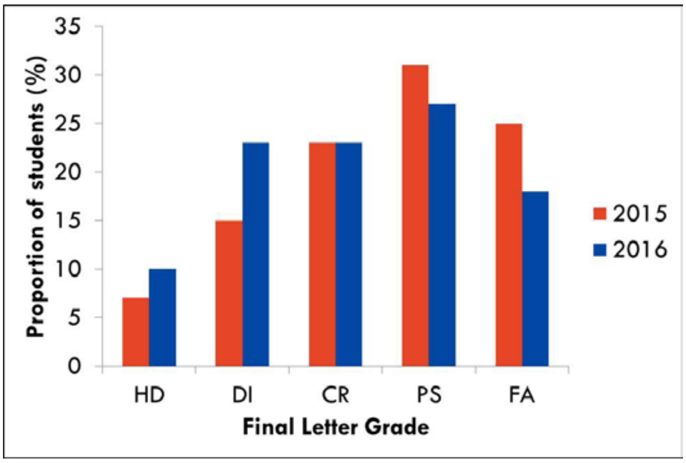

Figure 2: Student grades for second year core chemistry (Semester 1) in 2015 and 2016

CONCLUSION

The students have varying individual perceptions and experiences, but as a cohort more students are engaging with pre-lecture online resources than the lectures each week. At a minimum, students are now completing the weekly quiz and engaging with some of the content, and lecture attendance has improved according to the course lecturers. One problem with partially flipped learning may be that students feel they receive sufficient instruction from the pre-lecture resources alone. However, students may also not attend lectures due to scheduling conflicts. Student achievement in the course has improved from 2015 to 2016.

Additional interventions that may benefit students in the second semester of 2016 include using in-lecture polling technology at the beginning of weekly lectures. This allows lecturers to check students' mastery of key concepts and topics from the pre-lecture resources. Through a combination of the various data sources, it may be possible to predict the topics that students may find more difficult in the end-of-semester examination. Future analysis to be done includes data linkage on an individual student level over the semester to determine whether student engagement with pre-lecture resources leads to positive exam performance at a topic level. Finally, interviews will be carried out with some students to obtain a deeper perspective on their views on the partially-flipped learning approach.

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