Improving the undergraduate Science experience through an evidence-based framework for design, implementation and evaluation of flipped learning

Yvonne C. Davila
University of Technology
Sydney

Elaine Huber
University of Technology
Sydney

Jorge Reyna
University of Technology
Sydney

Peter Meier
University of Technology
Sydney

Flipped Learning (FL) is a student-centred pedagogical approach where new content is introduced prior to class which permits more time during class for active learning. Despite the growing body of evidence of the effectiveness of FL, many educators are reluctant to adopt this approach to teaching or are unsure of how to implement FL in their classes. Many students are uncertain of how to adapt their approaches to learning to a FL curriculum. In response to these challenges and calls for a robust framework to guide the design and implementation of FL, we developed the Flipped Teacher and Flipped Learner (FTFL) Framework based on the pedagogical literature. This paper reports on the use of our FTFL framework in the redesign of a large first year science subject from a traditional delivery to a FL delivery. We evaluated the efficacy of the redesign using a mixed methods approach with data on students' interactions with FL activities, and student and educator experiences. Findings from two iterations of the redesign indicate successful implementation of FL through high student engagement with online and class materials, and positive feedback from students and academics. Using the FTFL framework to guide the design and integration of FL, with an emphasis on clear communication, is key to our successful FL intervention and support of student learning.

Introduction

Flipped Learning (FL) is a pedagogical approach in which new instructional content is delivered before class, freeing up time for student-centred active learning during the class. This approach has gained traction in Science disciplines and lends itself to enquiry-based learning through active and collaborative tasks (Huber & Werner, 2016). Evidence of the effectiveness of FL is growing; however despite the evidence of the benefits of this 'new' approach (Weaver & Sturtevant, 2015; Rotellar & Cain, 2016) many educators are hesitant to adopt this change.

One of the reasons for this reluctance is the lack of a robust theoretical framework to guide the design, implementation and evaluation of the FL experience (Rotellar & Cain, 2016). A recent occasional paper written for the Australian Council of Deans of Science highly recommends that academics should 'embrace flipping' but there is no detail on *how* to implement this approach

(Overton & Johnson, 2016). There are educators who are willing to try FL but they may be unsure how to implement this approach in their own classes, particularly in large enrolment classes. Furthermore, students may have difficulty adopting this approach to learning because their expectations of how they learn are based on transmissive approaches (Chen, Wang, Kinshuk & Chen, 2014).

To address these challenges we developed the Flipped Teacher and Flipped Learner (FTFL) Framework (Fig. 1; Reyna, Huber & Davila, 2015) based on the literature of well known pedagogical approaches such as blended and student-centred learning, organisational appearance, universal design and evaluation. Our innovative FTFL framework includes seven elements: planning and pedagogy; storyboard and lesson plan; activity design (before, during, after class); organisation and presentation; building, testing, deploying; communication; and evaluation. The aim of this study was

to investigate the effectiveness of this FTFL framework for implementing FL and to measure the perceived learning gains of FL in a large science subject.
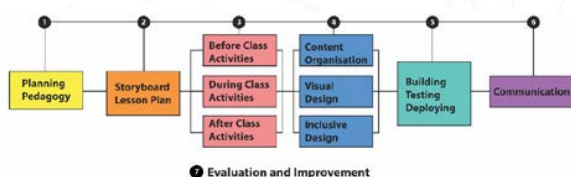

Figure 1: The Flipped Teacher and Flipped Learner Framework (Reyna et al., 2015)

Background

An institution-wide approach to blended learning has recently been rolled out across the University of Technology Sydney, which is the setting for the current study. Active and collaborative learning along with FL are key features of this initiative. 'Principles of Scientific Practice' (PSP) is a core first year subject for students enrolled in science degrees in the Faculty of Science (~850 students over two semesters). This subject introduces the major themes in science and inquiry-oriented experimentation, and focuses on developing scientific professional and communication skills. In 2016, PSP was redesigned to align with the university's blended learning strategy, with an emphasis on FL.

Learning design

Before the redesign, PSP was delivered with a traditional weekly lecture, one-hour weekly workshop and five laboratory sessions across the semester. The rationale for change to FL came through low student attendance at lectures and not enough time to apply newly learnt concepts in the workshops. A design-based research approach was used, following the FTFL framework and First Year Transition Pedagogy (Kift, 2009) to redesign the PSP curriculum and students' learning experience.

In contrast to other FL interventions we did not produce recorded lectures. Instead we purpose built interactive online modules to replace the lectures, with embedded short videos, written explanations of concepts, built-in questions and feedback (also see Davila & Griffiths, 2016). The modules were created with a content authoring tool (Adobe Captivate) and delivered every 1-2 weeks via the learning management system (LMS, Blackboard). Students could access the content at their own pace, and at a time and location that suited them. The face-to-face class time was conserved in new 2-hour workshops, designed using constructive alignment principles (Biggs & Tang, 2011) to ensure collaborative learning activities drew on the online content and built in feedback opportunities from peers and tutors. Students also completed short post workshop activities designed to consolidate their learning that week. The practical classes remained the same. After evaluating our first FL intervention and in response to

student feedback in 2016, we developed more questions for the existing modules to test students' understanding and created new modules and workshops targeting the assignment.

Research design

We evaluated the efficacy of implementing FL in PSP using a mixed methods approach, collecting data on students' interactions with FL activities, alongside student and educator experiences. Quantitative and qualitative data obtained from a student survey instrument were summarised and analysed using thematic analysis, respectively. The open-ended responses were coded (Saldana, 2013), and compared against the literature and the quantitative results. The student data were triangulated with the qualitative semi-structured interview data from the subject coordinator. The results and comments presented are from the surveys conducted after the first iteration of FL in 2016 and are a subset of a larger dataset from across different science subjects using the FTFL framework.

Preliminary findings & discussion

Engagement with content in the flipped classroom

Low attendance at lectures is a growing trend at universities and one influenced by a range of factors including assessment pressures, quality of teaching, timetabling clashes and work commitments (Dickson & Stephens, 2016). Average lecture attendance of around 60% has been reported for large subjects (see Yeung, Raju, & Sharma, 2016 and references within). Anecdotal evidence from our University suggests that lecture attendance tends to drop off towards the middle of the semester, sometimes below 50%, and increases again just before a revision lecture or pre-exams. In this study, completion of the online pre-workshop modules, which introduce the main concepts and replaced the lectures, remained high throughout the semester (Fig. 2). In semester 2 2016, three new online modules were introduced in weeks 9 and 11 that provide scaffolded instruction for writing the major assignment. Over 80% of students completed the first module in each series, but fewer completed the second and third module, resulting in the lower overall average completion for those weeks compared to earlier weeks. The decrease in module completions observed in week 9 also corresponded to a busy time in the semester when many assessment tasks are due. Overall, the average percentage of students completing weekly modules was between 76% and 87% for the first three semesters after the redesign indicating that a large majority of students engage with the online content and the FL model.
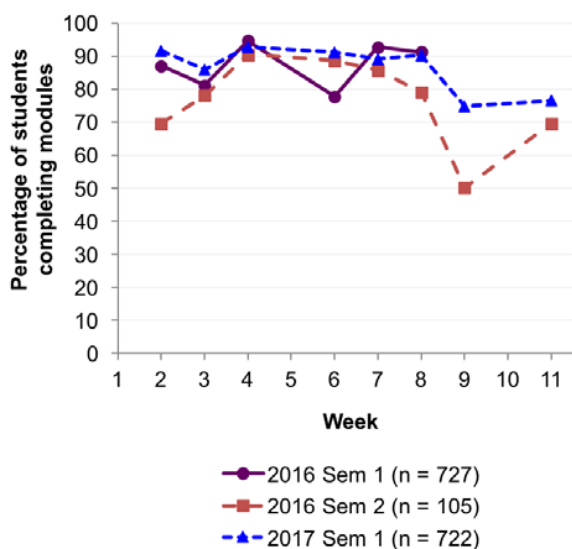
Figure 2: Percentage of students completing online pre-workshop modules over three semesters of FL delivery

The high percentage of online module completion throughout the semester also contrasts the common view that students will not complete pre-class activities or prepare for class (Kim, Kim, Khera & Getman, 2014; Rotellar & Cain, 2016). This is corroborated by positive student comments on their preparation and preferences for FL (Table 1). Most students reported that the online modules prepared them for learning in the workshops and this combination enhanced their learning (Table 2).

Table 1: Summary of students' comments from 2016 about PSP after the implementation of FL

Theme	Student comment
Flexibility and preparation for workshops	Being able to complete [the online modules] in my own time before the next workshop helped to create a less stressful learning approach … helped me to have the information for that said workshop, fresh in my mind.
Active learning in class	I wish more subjects were run like this. It is so much better. The workshops are really good for discussing ideas and clearing up confusion as you are able to discuss problems with a range of people.
FL compared to lectures	… it was great to do this [online modules] instead of sitting in a lecture as it allowed me more time to focus on other things and still learn.

Table 2: Student evaluation survey results after the first semester of flipped learning implementation in a large first year science subject (n = 567 respondents)

Survey item and % of respondents that agree and strongly agree	
There was a clear link between the online modules and the workshop activities	86.4
The online pre-workshop modules prepared me to learn in the face-to-face workshop	74.4
The combination of online modules and workshops enhanced my learning	69.5

However, we need to be wary of equating engagement with achievement as one does not necessarily lead to the other (Lucke, Dunn & Christie, 2016). As the subject coordinator reflected, some students "are so focused on getting results and marks that they don't really care about how they learn it so long as [the result] says 6/6 or it was completed, that's it for them, a ticked box".

Student satisfaction

Institutional feedback surveys conducted independently of our study indicate an improvement in student satisfaction with the subject after the redesign to FL, with survey scores increasing from 3.7 out of 5 in the traditional mode (2015) to 4.3 in the most recent semester using FL (2017). The high satisfaction scores validate the FL approach, particularly because PSP stands out as the only completely flipped subject in the first year science curriculum.

Despite these positive scores, a small proportion of students have criticised the subject content and FL approach: "I think all the info covered in the [online modules] could have been done in class." This criticism appears to stem from the perception that the material was too easy, had already been covered in high school, or was repeated in the workshops. This last point may suggest that some of the workshop activities were not challenging enough for some students. The introductory nature of the subject was intentionally designed to meet the learning needs of a diverse first year cohort: "I liked how the subject prepared first year students with no background knowledge in science with the tools they needed for their following years in science." The subject content, therefore, comprises concepts that may be familiar to students with some science background. This is a challenge when designing first year subjects. However, the overall survey results and comments indicates that the content is appropriately pitched and scaffolded for most students, including those new or returning to science at university: "Having not studied science for over 9 years it was a great introduction and refresher to help me get back into science and show me what is expected in university science related courses."

The subject coordinator reflected that some students' attitudes towards this subject were different and not in a positive way; some students "didn't treat PSP like a real subject because it didn't have lectures". He felt that this was perhaps due to their lack of maturity and knowledge of the different styles of delivery for learning. Activities used in FL do require students to be more accountable for their learning through class preparation (Rotellar & Cain, 2016). Better communication early on of how FL is used can mitigate this mismatch in student expectations and support student transition.

The subject coordinator pinpointed that a possible factor that may have led to some students' low satisfaction was the variety of active learning strategies used each week: "every week was different in terms of what the students did in the workshops and how they did it, and that may have been difficult for the students." The learning design team addressed this concern in the second and third iterations of the subject by reducing the number of online tools used, reordering the topics into a logical progression of skills development that align with the assignments, and streamlining the format of workshop activities. This may have contributed to the increase in student satisfaction scores observed.

### Student perception of learning

Over 69% of respondents (n = 567) agreed or strongly agreed that the combination of online modules and face-to-face workshops enhanced their learning in PSP, i.e. the FL approach enhanced their learning in this subject. This positive result aligns with the findings of several studies in Science disciplines (Huber & Werner, 2016). Unpacking this further, over 62% of students agreed or strongly agreed that both the online modules and collaborative workshops enhance their understanding (Fig. 3 top right hand corner). Only 3% of students reported that both online modules and workshops did not enhance their understanding in this subject (Fig 3. bottom left corner).

Communication and flipped learning

The importance of clear and regular communication was highlighted in this study in a number of ways. In the traditional mode of delivery, the subject coordinator stated that it was beneficial "having that open communication with [students] week to week and being able to diagnose any problems or issues as they happen". But in the FL mode the coordinator did not have any face-to-face classes with students and "If there was an issue in the workshops, I would only know about it if the [tutors] told me." This highlights the need for timely communication among all teaching staff in large FL subjects.

Initial feedback from the first student cohort of PSP in FL mode indicated that students needed reminding to complete the pre and post workshop tasks, despite the weekly tasks being documented in the subject outline and

LMS. Students who are unaccustomed to FL, especially in their first year of university studies, may require explicit guidance on how they should organise their out of class time to adapt to the FL delivery (Weaver & Sturtevant 2015). The subsequent redesign included a clear communications schedule for the subject coordinator and workshop tutors including 'just-in-time' weekly announcements. Training was provided to the tutors to ensure they understood the goal of the learning activities for each week. Tutors were also provided with PDF versions of the online modules to ensure they were familiar with the content and could confidently facilitate the workshop activities.
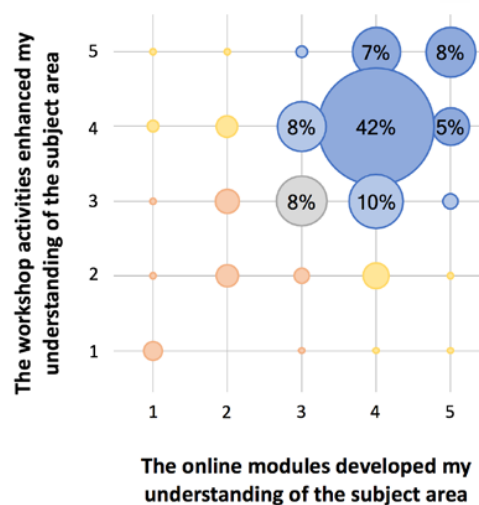
Axes are on a Likert scale, from 1 = strongly disagree to 5 = strongly agree.

The size of circles represents the number of respondents (total n = 567), with the percentage labelled. Circles without labels represent <2%.

Figure 3: Students' perceptions of how the components of flipped learning (online modules and face-to-face collaborative workshops) enhanced their understanding in the subject

Conclusion

Preliminary findings after the second iteration of a large first year curriculum redesign using our FTFL framework indicate successful implementation of FL through high student engagement with online and class materials, and positive feedback from students and the subject coordinator. Planning using the FTFL framework with clear communication of learning outcomes was key to our FL intervention and support of student learning. Other studies have proposed design principles for effective FL (Kim et al., 2014; Rotellar & Cain, 2016). Our framework builds on those principles and we propose the integration of an effective communication strategy to ensure students are aware of the *need* and the *how* of FL.

Previous studies have indicated a paucity of evidence on the effectiveness of FL in large cohorts (Khanova, Roth, Rodgers & McLaughlin, 2015) or that it is not a good fit for

first year cohorts (Persky & Dupuis, 2014). However, we concur with studies (Yelmarthi & Drake, 2015; Davila & Griffiths, 2016) who found that when support is offered through concept reinforcement during hands-on activities and timely feedback from the instructor, students can succeed in a FL environment. When planned well, FL brings a healthy variety for teachers, as noted by the subject coordinator: "it is a positive learning approach in that you can choose how the information is displayed and it doesn't just have to be [the lecturer] telling them one or two things … we introduced videos, quizzes, interactive elements."

We have shown that FL can be successfully implemented in a large first year science subject when the concepts are scaffolded in a way to meet the learning needs of a diverse cohort and class time is used effectively for active and collaborative learning. We have demonstrated that our FTFL framework (Reyna et al., 2015) is a comprehensive guide to the design, implementation and effective communication of FL for science disciplines, large enrolment classes and diverse first year cohorts.

Acknowledgements

References

Biggs, J., & Tang, C. (2011). *Teaching for Quality Learning at University: What the Student Does* (4th ed.). Berkshire, England: McGraw-Hill Education (UK).

Chen, Y., Wang, Y., Kinshuk, & Chen, N. S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education, 79*(1), 16-27. https://doi.org/10.1016/j.compedu.2014.07.004

Davila, Y.C., & Griffiths, N. (2016). Supporting student transition: embedding reading practices into the first year Science curriculum. *Proceedings of STARS Students Transitions Achievements Retention & Success conference 2016* (paper 12C). Perth, Australia. Retrieved from: http://unistars.org/papers/STARS2016/12C.pdf

Dickson, K. A., & Stephens, B. W. (2016). Standing room only: faculty intervention increases voluntary lecture attendance and performance for disadvantaged year 1 Bioscience students. *Higher Education Pedagogies*, *1*(1), 1–15.

Huber, E., & Werner, A. (2016). A review of the literature on flipping the STEM classroom: Preliminary findings. In S. Barker, S. Dawson, A. Pardo, & C.

Colvin (Eds.), *Show Me The Learning. Proceedings ASCILITE 2016* (pp. 267–274). Adelaide, Australia: Australasian Society for Computers in Learning in Tertiary Education.

Khanova, J., Roth, M. T., Rodgers, J. E., & McLaughlin, J. E. (2015). Student experiences across multiple flipped courses in a single curriculum. *Medical Education*, *49*(10), 1038–1048.

Kift, S. (2009). *Articulating a transition pedagogy to scaffold and to enhance the first year student learning experience in Australian Higher Education*: Final report for ALTC Senior Fellowship Program. Retrieved from FYHE Centre: http://fyhe.com.au/wp-content/uploads/2012/10/Kift-Sally-ALTC-Senior-Fellowship-Report-Sep-092.pdf

Kim, M. K., Kim, S. M., Khera, O., & Getman, J. (2014). The experience of three flipped classrooms in an urban university: an exploration of design principles. *The Internet and Higher Education*, *22*, 37-50.

Lucke, T., Dunn, P. K., & Christie, M. (2016). Activating learning in engineering education using ICT and the concept of "Flipping the classroom." *European Journal of Engineering Education*, *42*(1), 45-57. https://doi.org/10.1080/03043797.2016.1201460

Overton, T., & Johnson, L. (2016, July). *Evidence-based practices in learning and teaching for STEM disciplines*. Occasional paper, Deakin University. Retrieved from ACDS: http://www.acds-tlcc.edu.au/wp-content/uploads/sites/14/2016/07/ACDS-stem-principles-WEB.pdf

Persky, A., & Dupuis, R. (2014). An Eight-year Retrospective Study in "Flipped" Pharmacokinetics Courses. *American Journal of Pharmaceutical Education, 78*(10), 1–7. https://doi.org/10.5688/ajpe7810190

Reyna, J., Huber, E., & Davila, Y. (2015). Designing your Flipped Classroom: an evidence based framework to guide the Flipped Teacher and the Flipped Learner. *The 12th Annual Conference of the International Society for the Scholarship of Teaching and Learning* (pp. 91-92). RMIT Melbourne, Australia.

Rotellar, C., & Cain, J. (2016). Research, Perspectives, and Recommendations on Implementing the Flipped Classroom. *American Journal of Pharmaceutical Education*, *80*(2), 1–9. https://doi.org/10.5688/ajpe80234

Saldana, J. (2013). *The Coding Manual for Qualitative Researchers* (2nd ed.). London, England: SAGE.

Weaver, G. C., & Sturtevant, H. G. (2015). Design, implementation, and evaluation of a flipped format general chemistry course. *Journal of Chemical Education*, *92*(9), 1437-1448. https://doi.org/10.1021/cs.jchemed.5b00316

Yelmarthi, K., & Drake, E. (2015). Flipped First-Year Digital Circuits Course for Engineering and Technology Students. *IEEE Transactions on Education*, *58*(3), 179–186. https://doi.org/10.1109/TE.2014.2356174

Yeung, A., Raju, S., & Sharma, M. D. (2016). Online lecture recordings and lecture attendance: Investigating student preferences in a large first year psychology course. *Journal of Learning Design*, *9*(1), 55-71.

Contact author: Yvonne C Davila, Yvonne.Davila@uts.edu.au

Note: All published papers are refereed, having undergone a double-blind peer-review process.