A Flipped Classroom with Low-stakes Assessment to Maintain Student Engagement and Integrate Theory and Practice

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SESSION Integration of theory and practice in the learning and teaching process

CONTEXT We report on the use of a flipped classroom for an undergraduate course in Digital Systems in which weekly, low-stakes assessment is used to: encourage continuous engagement and provide continuous feedback; provide opportunities to apply theory to practice and to obtain meaningful assistance; and establish practices and incentives so that students can take responsibility for their own learning. Class records and student evaluations for the past 5 years show very high levels of attendance and student satisfaction. In this paper we evaluate the effectiveness of the approach more deeply. We also reflect upon the experience of teaching the course and consider its resource implications.

PURPOSE The purpose of this study is to determine to whether the low-stakes assessment of preparation and progress effectively contributes to student learning, and whether the flipped classroom succeeds as a platform for connecting theory and practice.

APPROACH In 2013 the course was changed from a conventional lecture series to a flipped classroom in which students prepare for their weekly class by reading, watching recorded presentations, and attempting exercise problems. During class, students work individually and in small groups on problems that are more open-ended and may require discussion in small groups, searching for solutions or resources, or practical design and implementation. Attempting the preparation and class work is sufficient to be awarded the marks for the tutorial. Student evaluations and results since 2010, as well as a dedicated survey administered this year, have been used to evaluate the effectiveness of this approach.

RESULTS Student evaluations show a statistically significant improvement in reported attributes including development of thinking skills, effective feedback, and overall satisfaction with course quality. Students' opinion of the workload has not changed, with over 97% agreeing that it was appropriate before and after the change. Flipping the classroom has not had a significant effect on exam results, which were appropriate before the change. An anonymous online survey was completed by 92 students who recently completed the course. 98% agreed that the course helped them understand the connection between digital systems and practice, and 93% agreed that marks for the tutorial encouraged them to attempt the preparation.

CONCLUSIONS The flipped classroom with low-stakes assessment recieves positive student evalutions and is a satisfying teaching experience for the lecturers with a workload no greater than that accounted for a conventional lecture course in the authors' school. Most students find the low-stakes assessment a useful motivator, prepare appropriately for tutorials, and agree that the flipped classroom facilitates development of both theoretical understanding and practical skills.

KEYWORDS Flipped classroom, Low-stakes assessment, Assessment for learning

Introduction

Although there are various definitions of a flipped classroom, most share the notion that students prepare individually before class, and work interactively in groups during class time (Bishop and Verleger, 2013). There are many potential benefits to this approach and it has received a lot of attention in recent years. A 2015 survey of 1089 college faculty, mainly from North America, found that 75% had tried a flipped approach (Faculty Focus, 2105). But the flipped classroom is not without pitfalls. The same survey found that 5.5% of respondents would not try the approach again.

In 2013 we flipped the classroom of a third year course on Digital Systems at the University of Adelaide. The existing course used a format that was typical in our school at the time, with 3 lectures a week and fortnightly class tutorials. Neither student satisfaction nor achievement were problems, as the course was rating well in student evaluations and grade distributions were within appropriate bounds.

Nonetheless, we had several motivations to make a change. Key among them was a desire to give students more experience with open-ended design problems, and more opportunities to put theory into practice. We were also inspired by the promise of a pedagogy that would develop independent, student-centered learning, and also would provide meaningful support for students when they need it.

The change has been a success with the flipped classroom providing many more opportunities for active and collaborative learning in which theory is applied to practical problems. Student satisfaction has improved, student achievement has remained high, and students agree the workload is appropriate. More details are provided in the Evaluation section.

Aware of some of the pitfalls in flipped classrooms, we introduced weekly low-stakes assessments. These provide incentives for students to maintain engagement with the course, prepare before classes, and complete class work. We believe they have been critical for the success of the course. To better understand student attitudes to the weekly assessment, and the flipped approach more generally, we issued an online survey to students who completed the course in Semester 1 2017. The results of this survey are also presented in the Evaluation section.

Context

Flipped Classrooms

For their survey of the research into flipped classrooms, Bishop and Verleger (2013) chose to define the flipped classroom as “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom.” This definition is helpful for explaining the appeal of the approach. Using technology it is possible to shift teacher-centric or didactic learning activities online so that students can complete them at their own pace, at times that best suit them. This frees staff time for student-centered learning, which happens best face-to-face. If good quality lecture recordings are available, then flipping the classroom is a ready opportunity to expand the student-centric aspects of a course and thereby employ some of the many well-established student-centric paradigms such as peer-assisted learning, problem-based learning, and active learning.

The Faculty Focus (2015) survey of teachers who had tried flipped classrooms reported that: 75% of respondents saw greater student engagement; 55% saw evidence of improved learning; and 80% said students were more collaborative.

Case studies reporting the effects of flipping a particular course have been published for a wide variety of disciplines. For example, within our own discipline, Papadopoulos & Roman (2010) reported faster progress and improved test achievement for a flipped course in electrical engineering. Of particular relevance, Warter-Perez and Dong (2012) flipped a class to "embed inquiry and design projects into a digital engineering lecture". These motivations have much in common with our own. They reported that the change improved students' understanding and design skills.

Not all studies report unqualified success. A carefully controlled study of an undergraduate civil engineering course by Hotle and Garrow (2016) found that quiz performance did not change significantly, and that students take time to adapt to the flipped format. The authors caution that, "the method could increase the frustration of weaker students at the beginning of the course." They also find that the inability of students to ask questions during the recorded lectures is a critical issue and that most of the questions asked in class were related to the class problems, not the lecture material. Our response to this concern has been to ensure that the lecture-material and the in-class activities are well aligned. If the class activities require direct application of the lecture theory then questions about one will help understanding of the other.

A second concern about flipped classrooms is that it "undervalues the power of good, engaging, face-to-face Socratic teaching" (Hamdan, McKnight, KcKnight and Arfstrom, 2013). This is reflected by one professor's response to the Faculty Focus (2015) survey:

> *Students wanted me to lecture, tell stories, ask questions, and stimulate discussion. They did not want to try and learn the material themselves. They did not feel empowered. They did not see me as a co-participant. They wanted me to be in charge.*

Our observation is that the flipped classroom is not mutually exclusive with Socratic teaching; quite the opposite with the small group classes providing a much better forum for meaningful discourse than large lectures.

A challenge of particular relevance to this study is clearly expressed by Faculty Focus (2013):

> *one consistent area of concern among faculty is student motivation. The attitude seems to be that if students don't do "traditional" homework assignments that involve reading, writing, and preparing for class, what makes us think they would watch a video or prepare for class using different approaches just because we call it a "flipped" classroom?*

We shared this concern when we planned our flipped class and turned to principles from 'assessment for learning' to address it.

Assessment for Learning

For our flipped classroom to work as we intend it is critical that students prepare before classes. They require a baseline of knowledge to be able to attempt the class activities, and they need to know what they don't understand so they can seek assistance. It all hangs on the students taking sufficient responsibility for their own learning to spend time preparing outside of class.

Development of self-managing, reflective learners is one of the goals of 'assessment for learning' (Broadfoot et. al. 2002):

> *Assessment for learning is the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there.*

To be able to decide where to go, and how to get there, a learner needs clear goals and appropriate feedback. Nicol and Macfarlane-Dick (2006) formalise this process in a model of 'self-regulated learning' and describe seven practices of good feedback to support it.

For our flipped classroom we introduced weekly low-stakes assessments of preparation and class work to give students the necessary incentive and feedback to become self-regulated learners. Further details of the assessments, and their relationship to Nicol and Macfarlane-Dick's seven practices are provided in the following section. The effectiveness of the scheme is considered in the Evaluation section.

Course Design

In 2013 we flipped the classroom of our established third year undergraduate course on Digital Systems. The new course satisfies Bishop and Verleger's (2013) definition of a flipped classroom with weekly interactive face-to-face classes and individual computer-based preparation before classes. Using their classification the new course is fully flipped, with in-class activities consisting of small-group activities and homework (individual activities), and out-of-class activities consisting of video lectures, reading, and homework exercises.

In the flipped format each student attends a 2-hour class once a week. A lecturer and a tutor are present at every class and spend time individually with every student. The class instructions specify preparatory lectures, reading and exercise questions that focus on foundation theory and skills. The in-class exercises are more open-ended and may require discussion in small groups, searching for solutions or resources, or practical design, simulation and implementation using computers and reconfigurable logic circuits. Classes also include a mini-lecture or discussion focusing on an aspect of the course the students are finding challenging.

This arrangement is intended to promote the integration of theory and practice by building the foundations of theoretical understanding in pre-class preparation; then consolidating understanding and integrating it with practice in the class. The course learning outcomes and learning activities are carefully aligned to ensure this works. The learning outcomes are expressed in terms of practical capabilities and the learning activities involve direct application of these capabilities. For example, one of the Digital Systems learning outcomes is to "be able to design, build and test digital logic for systems of moderate complexity using common digital components, schematic diagrams, and hardware description language." This outcome is the focus of a number of weeks in the course, each of which involves design and analysis of a digital logic system for preparation, and then implementation, testing and simulation in the class.

Digital Systems is an ideal topic for learning about design. The underlying circuit technology is well understood so that students can focus on big picture challenges such as designing power efficient architectures. Systems of moderate complexity can be quickly realised in reconfigurable hardware. This provides an excellent training ground as students can see their designs in action, experiment with alternatives, and appreciate the applications of the skills they are developing. For our flipped classroom, to give the students more opportunity to practice and experiment outside of classes, they are loaned a reconfigurable logic development board for the duration of the course. They bring these to classes and work in groups to build useful systems. They can also use them in their own time, at home or in the university computing suites, either to finish the assessed tutorial questions or just for practice.

During the class the teaching staff sit with each student individually, discuss and quickly assess their preparation, and provide help as required. They take every chance to branch into a broader discussion about design or engineering practice. Students keep an exercise book in which they record preparation exercises, tutorial problems, lecture notes and practice problems. During the one-on-one discussions the teacher stamps the student's exercise book and records a mark for preparation and another for completing the exercises from

previous class. Full marks are given for attempting all the problems, and checking the answers against the published solutions. The marking is not time consuming and only contributes 15% of the final grade.

As discussed above, the goal of this assessment is not to drag unwilling students through the course, but to create structures and incentives to help students take responsibility for their own learning. To a greater or lesser extent, it meets all seven of the principles from Nicol and Macfarlane-Dick (2006):

1. helps clarify what good performance is: by having exercises and activities that are directly aligned to the learning outcomes and typical of questions in the summative assessment.
2. facilitates the development of self-assessment (reflection) in learning: students check their own answers against published solutions and seek assistance when they cannot reconcile the differences; some exercises every week explicitly require reflection on learning.
3. delivers high quality information to the students about their learning: teachers provide timely face-to-face feedback on progress and achievement.
4. encourage teacher and peer dialog: using small group activities that involve explaining concepts to peers, and during one-on-one discussions with teachers.
5. encourage positive motivation and self esteem: by having “frequent low-stakes assessment tasks, with feedback geared to providing information about progress and achievement, rather than high-stakes summative assessment tasks where information is only about success or failure, or about how students compare with their peers” (Nicol and Macfarlane-Dick, 2006).
6. provides opportunities to close the gap between current and desired performance: by making available a large set of alternative practice exercises so that students can re-attempt challenging problems.
7. provides information to teachers that can be used to help shape teaching: patterns emerge form one-on-one discussions that indicate concepts or skills the students are finding difficult.

Evaluation

Methdology

The Digital Systems course ran for 3 years in a conventional format and 6 cohorts have now competed the flipped version. Anonymous course evaluation surveys have been issued to every cohort. The surveys use a Likert scale from 1 to 7 and the results below give combined means and standard deviations computed for the two populations. Unfortunately some of the questions were changed in 2012 so that the results for these questions from 2010-11 cannot be used for this study. Aggregate course evaluations for every course from the School of Electrical and Electronic Engineering are also available. Only statistically significant increases are claimed according to a one tailed t-test at a significance of 95%. Figures claimed for agreement indicate the percentage of students who responded with 5, 6 or 7. Primary exam results are also available for the two populations and they have been compared using a two-tailed t-test at 95% confidence.

An additional online survey was issued to the cohort of 204 students who completed the course in semester 1 this year. Once again a 7-point Likert scale was used with responses 5, 6 and 7 indicating broad agreement.

Results

Table 1 shows student evaluation responses for the course before flipping, all courses in the same school over the same interval, the course after flipping, and all courses in the same school over the same interval. Student evaluations for all questions that have been asked consistently since 2010 have improved since the classroom was flipped. In addition, for every cohort since the class was flipped, over 95% of respondents agreed that the course "has a workload that is appropriate for the achievement of its learning outcomes". Table 1 also shows that aggregate results from the school increased for the period after the class was flipped. This confounds the results and makes it difficult to attribute the improvements to the flipped classroom; however we can observe that the measures for the flipped class are all higher than those for the school over the same period.

Table 1 also shows the student evaluation results for two relevant questions that were added to the survey in 2012. For these two questions there is insufficient data prior to flipping the classroom to be able to claim an improvement with 95% confidence.

Table 1: Student evaluation responses for the course before and after flipping and aggregate results for all courses in the school over the same intervals. Results are given as *mean* (*s.d.*).

	Unflipped (2010-12)		**Flipped (2013-17)**	
Questions asked since 2010: The course…	**Course *n* = 103**	**School *n* = 1923**	**Course *n* = 223**	**School *n* = 5408**
uses methods of assessment that help me achieve its learning outcomes	5.9 (1.1)	5.3 (1.4)	6.23 (0.8)	5.7 (1.4)
helps me to develop my thinking skills	6.1 (1.0)	5.6 (1.3)	6.37 (0.7)	5.7 (1.3)
has a learning environment that takes into account student diversity	6.0 (1.0)	5.6 (1.3)	6.31 (0.8)	5.7 (1.3)
supports my learning with effective feedback	5.7 (1.2)	5.1 (1.5)	6.31 (0.8)	5.5 (1.5)
Overall, I am satisfied with the quality of this course.	6.1 (1.0)	5.4 (1.3)	6.37 (0.7)	5.6 (1.5)
Questions asked since 2012:	***n* = 29**	***n* = 749**	***n* = 223**	***n* = 5408**
has clearly identified learning outcomes	6.2 (1.2)	5.9 (1.1)	6.3 (0.7)	5.8 (1.2)
uses appropriate strategies to engage me in my learning	6.0 (1.1)	5.6 (1.3)	6.3 (0.8)	5.5 (1.5)

The average primary exam mark for the 223 students who took the course prior to flipping was 65% (17%); for the 553 students who have completed the flipped course it is 63% (18%). There is no statistically significant change and the marks distribution was appropriate before and after the change.

While class attendance should not necessarily be a goal in itself, in the case of the flipped class it is an indicator of engagement with the course. Total tutorial attendance for the flipped class has been 95%. Students have been awarded marks for preparation on 94% of occasions. 93% of students have attended 10 or more of the 12 tutorials.

In the weekly low-stakes assessment, half of the marks are for attempting the preparation, and half for completing the previous week's in-class questions. Four questions in this year's survey explored student attitudes towards this assessment. The results are summarised in Table 3. Over 93% of respondents agreed that the marks encouraged them to attempt the preparation and the in-class questions and over 93% attempted almost all or all of the questions most of the time. The results also show that there are a few respondents who were not encouraged by the marks.

Did students prepare effectively for classes? Importantly, all but 3 of the 92 respondents to the survey agreed the preparation questions helped them achieve the learning outcomes. 80% of respondents listened to the recorded lectures frequently or more often, and over 94% agreed they helped them achieve the learning outcomes. The questions about the textbook

reveal a variety of study habits. Over 20% of students read the textbook weekly as part of their preparation; 12% never read it. Presumably, between these extremes students dipped in to the book when help was required with over 70% agreeing that it helped them achieve the learning outcomes.

Table 3: Survey results for questions related to low-stakes assessment. 92 respondents.

	always \ strongly agree \ all of them	usually \ mostly agree \ almost all of them	frequently \ slightly agree \ just more than half	about half the time \ undecided \ about half of them	occasionally \ slightly disagree \ just fewer than half of them	seldom \ most disagree \ almost none of them	never \ strongly disagree \ none of them
Questions related to low-stakes assessment							
The tutorial marks encouraged me to attempt the preparation:	57	18	11	1	2	2	1
How many preparation questions did you attempt most of the time?	45	41	5	1	0	0	0
The tutorial marks encouraged me to attempt the in-tutorial questions:	53	21	15	1	1	0	1
How many in-tutorial questions did you attempt most of the time?	43	44	3	2	0	0	0
Questions related to preparation							
I listened to the week's recorded lectures before coming to the tutorial:	37	27	10	11	3	2	2
The recorded lectures helped me achieve the course learning outcomes:	29	44	14	3	2	9	9
I read sections from the textbook before coming to the tutorials:	19	12	14	13	12	11	11
The textbook helped me achieve the course learning outcomes:	19	27	19	13	8	5	1
I made a genuine attempt to complete all of the preparation questions before the tutorial:	52	27	9	3	1	0	0
The preparation questions helped me achieve the course learning outcomes:	43	39	7	2	1	0	0
I took a short-cut in the preparation and copied solutions without making a genuine attempt:	1	5	5	8	20	34	18
Questions related to theory and practice							
The flipped classroom helped me understand the theory of digital systems:	29	45	10	5	1	0	2
The flipped classroom helped me learn practical skills in digital systems:	38	34	13	3	1	1	2
The course helped me understand the connection between digital systems theory and practice:	40	40	10	1	0	0	1

Over 89% of respondents usually made a genuine attempt to complete all the preparation questions. The other side of this is that there are a few students who do not take the opportunity to prepare before classes. As all the solutions are available in advance, it is possible for students to take a short cut and copy solutions without genuinely attempting the problems. 19 of the 92 respondents admitted they copied some solutions at least half the time.

The last part of Table 3 shows survey results for questions related to the integration of theory and practice in the course. 91% of respondents agreed that the flipped classroom helped them understand the theory; 92% agreed that it helped them learn digital systems; and 98% agreed the course helped them understand the connection between theory and practice.

For a cohort of 120 students, a lecturer and tutor attend four 2-hour classes a week. Once we account for lecture preparation and practical demonstrator costs for the un-flipped course, the teaching costs are only slightly higher for the flipped version, and still within the budget for a course in the authors' school. There are higher contact hours for the lecturer but in our experience this is justified by an improved educational experience for the students and a much more satisfying teaching experience for the lecturer.

Conclusions

The flipped classroom incorprating small-group exercises, design, implementation, and lecturer-led discussions has increased the focus on design and the interplay between theory and practice. Weekly low-stakes assessments maintain the course tempo and provide the necessary framework for most students to develop as self-regulated learners. A handful of students who do not grasp this opportunity, and are left behind by the process. We do not know yet if these students also achieve lower grades for the course, although this seems likely. The close interaction between staff and students in the flipped format means there is scope to identify these students early and provide assistance.

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