

# The transition from traditional face-to-face teaching to blended learning – implications and challenges from a mathematics discipline perspective

**Birgit Loch**

Department of Mathematics, Faculty of Science, Engineering and Technology  
Swinburne University of Technology

**Rosy Borland**

Faculty of Science, Engineering and Technology  
Swinburne University of Technology

Despite the drive at Australian universities towards blended learning, the research on the effectiveness and successful implementation of this model is lagging behind in some disciplines. In this paper we highlight the need for targeted research into blended learning in mathematics at more than an individual unit scale, particularly in the context of the flipped classroom. The literature on the flipped classroom in mathematics is limited to reports from enthusiastic individuals who have flipped their units with more or less success, with no reports on the sustainability of these implementations. We take the perspective of a discipline that already faces certain challenges with respect to student preparedness and special needs to facilitate online learning. From the literature, we extract research questions that need to be addressed urgently, and that may in the future be used to form a discipline-specific framework for introducing blended learning.

Keywords: flipped classroom, mathematics education, blended, discipline specific challenges

## Introduction

Online learning is not new to higher education and has been extensively researched, particularly at universities that specialize in teaching students online. Blended learning, the combination of the online and face-to-face domains, however has more recently been included in learning and teaching strategies of Australian universities that have been more focused on face-to-face teaching (e.g. Swinburne (2014) and UWS (2012)). An example of implementation of such a strategy is the faculty-wide blended learning project in the Faculty of Science, Engineering and Technology at Swinburne University of Technology. It was established to contribute to the university's goal of achieving 50% of student learning at Swinburne University delivered online by 2020 (Swinburne, 2014). The first stage of this project will see around 20 first year units re-developed into a blended learning mode by the end of 2015, with a number of these being mathematics units.

From a review of the literature on “flipping the classroom” in tertiary mathematics education, this paper looks at issues and implications of introducing blended learning in mathematics on a larger scale. Most of these issues have not been addressed adequately in the literature. Mathematics is a symbol-based discipline that has traditionally faced particular issues when teaching in online mode (Smith & Ferguson, 2004) and that has also been struggling with fewer students undertaking higher level secondary mathematical studies before entering university (AMSI, 2014) and increasing student under-preparedness in Australia (Rylands & Coady, 2009). This paper highlights the urgent need for more research into larger scale implementation of blended learning in mathematics by stating the most pertinent research questions that remain unanswered in the literature. We highlight the perspective of a particular discipline in moving to blended learning (some of the questions may relate to all disciplines) to guide the direction of the research and also start conversations at the conference.

We will first briefly discuss traditional lectures in mathematics education and then explain the difficulties faced teaching mathematics online. This is followed by a review of the literature on flipping the classroom in mathematics, from which we extract the research questions.

## Tertiary teaching in the mathematics discipline

### Lectures in mathematics education

Traditional lectures are still predominant in tertiary mathematics education, for three reasons. One lies in limited

resources and cramped curricula (Donovan & Loch, 2013). The second is that moving away from the centre stage and full control in the classroom doesn't come naturally to many mathematics lecturers who themselves were taught in "chalk and talk" form and have not experienced other forms of learning in the classroom. Thirdly, there is a belief that mathematics is different from other disciplines and there is no need to move away from lectures, as it is "unusually strongly structured and objective", and because mathematics education "deploys lectures differently from many other disciplines" (Pritchard, 2010; also see references therein). Pritchard also claims that since students are human rather than simply rational beings, teaching needs to address "'affective' factors such as habit, enthusiasm and identity, as well as 'cognitive' factors related to learning", which can all be addressed in lectures. In Pritchard's view, the three functions a lecture fulfills are communicating, modeling, and motivating, "consolidated and extended through individual and group activities and regular feedback", with students involved in active processes rather than passive knowledge transmission.

### **Teaching mathematics online**

Teaching mathematics online has been recognized as complex due to the visual nature of the discipline (Smith & Ferguson, 2004). Discussions often rely on typed communication using mathematical typesetting displayed in awkward LaTeX-style formalisms (Loch & McDonald, 2007); this can result in one-way communication as students find it difficult to respond in kind. While graphical palettes have improved significantly over the last few years and may provide alternatives for typing mathematical documents (Loch, Lowe & Mestel, 2014), the issue of immediate and synchronous online communication of mathematical working such as graphs and work-in-progress handwritten calculations ideally is facilitated by access to tablet technology for both lecturers and students, and web conferencing software with shared whiteboard facility (Reushle & Loch, 2008) for step-by-step explanation of solutions. To support students online and to record additional explanations for students outside face-to-face hours, screencasting software has been suggested (Loch, Gill & Croft, 2012). In addition, online assessment in multi-choice format often tests recognition rather than mathematical understanding and answers may be reverse-engineered (see example by Donovan & Loch (2013)). By moving assessment online, there is concern that the development of deeper mathematical understanding that occurs during practice may be impacted as students may be "doing" less mathematics because they no longer write it out (Loch, Lowe & Mestel, 2014). We note that while universities experienced in online education have necessary IT infrastructures in place to facilitate online mathematics learning, others with a focus on face-to-face teaching may not.

### **Literature on flipping the classroom**

The "flipped classroom" is a current catch phrase for changing the way we teach. This is one example of a blended learning approach, which encompasses a move away from transmissive lectures where students listen and take notes, to student-centred face-to-face sessions where students actively participate "by doing" (Prince, 2004). These sessions are often combined with online study that exposes students to concepts before they come to a face-to-face class. Face-to-face time is then used more effectively to develop a deeper understanding "rather than the shallow repeating of material from a text book". When all learning activities are carefully selected and aligned, students may benefit from the best of online and face-to-face education.

This review of relevant literature on flipping the tertiary mathematics classroom is grouped into three themes: student engagement, evaluation and mathematics discipline specifics.

#### **Student engagement**

One strategy for facilitating active learning in the face-to-face environment is peer-instruction in conjunction with audience response systems, also known as "clickers", to facilitate instant feedback. Clickers have been used successfully for student active learning (Caldwell, 2007), and enable lecturers and students to gauge in real time how much has been understood so focus can be placed on addressing misconceptions (Kowalski et al., 2009). There is strong evidence that students appreciate a move away from transmissive lectures towards highly interactive, technology-enhanced mathematics classes that allow students to contribute their work to the discussion (Donovan & Loch, 2013).

The "flipped classroom" model places the onus on students to prepare for class and encourages students to take ownership of their learning. To be successful, the model requires students to "develop the skills to self-regulate their own performance and become aware of the gaps in their understanding of complex conceptual tasks". Suggestions for encouraging students to undertake the pre-class preparation range from providing an incentive (Brame, 2013) to holding students accountable for pre-class activities (Bagley, 2014). It also requires the designers of learning resources such as screencasts to ensure that "the pedagogical approach encourages and

promotes self-directed [...] or self-regulated learning” (Loch & McLoughlin, 2011). However, we question that students with weak pre-requisite skills have, or can quickly develop, self-regulatory skills needed to engage with this form of learning. Mathematics educators have encountered this issue for decades (Rylands & Codie, 2009).

## **Evaluation**

A list of key elements for flipping the classroom (Brame, 2013) and good practice guides in the context of mathematics teaching (Bagley, 2014) do exist, however the literature is scarce with regard to how the implementation of flipped classrooms across a whole department, faculty or university has impacted on the discipline of mathematics. Reports from individual teachers relating to student engagement, learning, performance and perception can be found—with mixed results. These include a successful trial in the related discipline of statistics (Khan, 2013) where students were expected to read through material before class. In this trial, an audience response system was used in lectures to facilitate quizzes and students were expected to then participate in group discussions. This resulted in higher lecture attendance rates, improved exam performance and a larger number of top performing students. On the other hand, a comparison of different strategies in teaching calculus showed no statistically significant difference in exam results (Bagley, 2014). Another comparison in calculus demonstrated higher performance in the flipped classroom but also showed 22% of students were not engaging at all with the online content that was expected to be studied before class. This occurred despite class time including both an entrance quiz linked to the video and group work solving problems based on the video (McGivney-Burelle & Xue, 2013). This large percentage of students not participating in online activities is very concerning, and indicates that it may not be easy to ensure students interact with both online content and classroom activities. More flexibility may need to be included for students to recover if they have not watched a video beforehand or have not attended class. Comparison of teaching methods in a further calculus unit showed that student performance on conceptual items improved, with students more likely to connect procedures to new ideas (Code et al, 2014) after undertaking pre-reading, and participating in group discussions with an audience response system. Finally, a meta-analysis of 225 studies on active learning versus traditional lecturing in STEM disciplines has shown that students learning via traditional lectures are 1.5 times more likely to fail than students in active learning classes (Freeman et al, 2014), and exam scores improved by 6% on average in active learning environments. The same authors, however, comment that “it is an open question whether student performance would increase as much if [...] active learning approaches” were implemented in all classes within a department.

These examples from the literature reporting on outcomes from flipped classroom implementations indicate that it is unclear how best to judge such implementations and if (and how) all of the following should be monitored: class attendance, online activity, student performance, drop-out rates, observed level of student engagement in face-to-face classes, student and staff perception, and deeper understanding of mathematical concepts.

## **Mathematics discipline specifics**

While there appears to be an expectation in the literature that face-to-face classes in the flipped classroom involve technology, we point to a recent paper by Seaton et al. (2014) which describes “board tutorials”—tutorials held in learning spaces with no seating and with blackboards along the walls, thus encouraging students to collaborate in solving mathematics problems on the boards, and “doing” the mathematics in class by developing solutions in front of other students and teaching staff. This approach has, over decades, led to student engagement and high tutorial attendance, and has spread to a number of universities. However, at the same time we have observed that blackboards are being removed from universities around the world and replaced by document cameras which provide less space to “lay out the mathematics” (for example, in proofs). Such limitations in physical learning spaces will make it more difficult to adopt active learning approaches in the classroom unless some other means of sharing the handwriting of mathematics by students is used (e.g., the high-tech approach described by Donovan & Loch (2013)).

## **Research questions to guide future research and conclusions**

The literature about the potential benefits of “flipped learning” is not convincing. In particular, there is little evidence that “flipping the classroom” is easy to achieve or maintain, necessarily leads to enhanced student learning, or is scalable to a whole department. We have drawn the following seven research questions from the literature. We believe they deserve urgent attention:

1. What can we do to ensure students engage with both online content and classroom activities?
2. How can we encourage school leavers enrolled in first year mathematics units to self-regulate their learning?

3. How can we build in redundancies, eg. enable students to recover if they have not watched a video beforehand or have not attended class?
4. What technology is needed to enable effective online communication and collaboration to support learning in Mathematics?
5. What technology is needed to support deep learning of mathematics? What new technologies might be on the horizon? What impact can learning spaces have on student engagement?
6. On a departmental level, what is the best approach for supporting teaching staff (including sessional staff) to develop and implement innovative pedagogy approaches, promote digital content creation and use technology to enhance learning and teaching outcomes?
7. How do we measure the success of a flipped classroom?

Our search of the literature has shown us that there is no single approach to developing a blended learning unit. The approach taken depends on circumstances such as available learning spaces, financial constraints, teaching and tutoring staff skills, student needs, content, year level, but also university or faculty direction with regards to blended learning. With budget pressures in the Australian higher education sector, we expect a push towards more blended or entirely online learning. This leads us to the question “Can we afford not to flip?” in an era of open educational resources and MOOCs. Therefore we urge the educational technology and mathematics education research communities to undertake research focusing on answering the questions posed above.

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**Contact author:** Birgit Loch, [bloch@swin.edu.au](mailto:bloch@swin.edu.au)

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