Flipping the Classroom:
A Case Study of a Mathematics Methods Class

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The “flipped classroom” is gaining popularity in a number of settings, including secondary schools, reflecting a belief that the approach is more engaging and effective for students. This paper reports on a senior secondary mathematics class’s experience with adopting a flipped classroom approach. The findings indicate that the teacher and students were positive about the practice and perceived it as being sustainable and transferable to other classes. The study has particular implications for senior secondary mathematics teachers who often find it challenging to cover the syllabus and prepare their students for externally imposed assessment tasks.

The concept of the flipped classroom, or flipped learning, dates back to the turn of the millennium (e.g., Lage, Platt, & Treglia, 2000), with one of the best-known accounts being that of Bergman and Sams (2012) chronicling their own experiences in a high school chemistry classroom. There they used digital technologies to record lectures and demonstrations for students to download and access wherever and whenever it was convenient. As Hamdan, McKnight, McKnight, and Arfstrom (2013) discuss, this then frees class time to work on exercises, activities, and in-depth interactions among students and teachers. Many tertiary educators may be familiar with this model of instruction, with videos replacing traditional lectures, but it has only been recently adopted by classroom teachers in high school and senior school settings. While there is a plethora of resources available online about how to implement the approach, and some anecdotal accounts of teachers’ experiences, the research in this area is scant, particularly in terms of documenting students’ experiences. Hamdan et al. suggest that adopting the flipped classroom has resulted in improvements in student performance and, while limited, they highlight that the research is promising and warrants further inquiry. This paper adds to the limited research in this field through reporting on data collected from a senior secondary mathematics teacher and his students who were enrolled in a Grade 11/12 Mathematics Methods class at a large secondary school. The results will inform mathematics teachers and educators about the practice of flipping the classroom in mathematics, the benefits or otherwise of using teacher-generated video demonstrations and readily available materials from internet sites, and how and why students make use of these resources.

Theoretical Framework

The Flipped Classroom

According to Hamdan et al. (2013), in the flipped classroom model, teachers may record and narrate screenshots of work they do on their computer screens, create videos of themselves teaching, or curate video lessons from internet sites such as *TED-Ed* and *Khan Academy*. Not only is it claimed that this maximises teacher instruction, Bergman and

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Sams (2012) advocate that it "speaks the language of today's students" (p. 20). Students are increasingly online, interacting in and with sites such as *YouTube* and *Facebook*. Education policies such as the Melbourne Declaration on Educational Goals for Young Australians (MCEETYA, 2008, p. 5) state that

> Rapid and continuing advances in information and communication technologies (ICT) are changing the ways people share, use, develop and process information and technology. In this digital age, young people need to be highly skilled in the use of ICT. While schools already employ these technologies in learning, there is a need to increase their effectiveness …

The flipped classroom model takes advantage of students' propensity to be online and allows students to extend their knowledge "at a pace, in a place and with an educational purpose that suits them" (MCEETYA, 2003, p. 4). In terms of catering for students' learning, the reduction in time spent on in-class teacher presentation and explanation means that teachers can capitalise on students' preparation and devote more class time to allowing students to integrate and apply their knowledge, checking on each student's understanding, and helping to develop students' procedural fluency (Hamdan et al., 2013).

In order for learning to occur in a flipped classroom, four key features have been posited (Hamdan et al., 2013). These are flexible environments, a shift in the learning culture, intentional content, and professional educators. The flexible environment can involve physical rearrangement of the classroom space but generally refers to teachers acknowledging that a focus on students' learning may mean a variety of approaches, learning locations, and timelines. The shift in learning culture incorporates the deliberate change from a teacher-centred classroom to a student-centred approach "where in-class time is meant for exploring topics in greater depth and creating richer learning opportunities" (Hamdan et al., 2013, p. 5). Intentional content refers to the need for teachers to evaluate what content to teach directly (and when/how), and what materials students should be allowed to explore on their own. The fourth pillar recognises that teachers need to know their own students and optimise the approach needed to help each student learn best. It acknowledges that the flipped approach cannot replace educators, but that, indeed, the role of the educator is a demanding one that requires them to evaluate the affordances of the model.

Advocates of the model have outlined a range of benefits for students, including increased time (and support) for completing what were traditionally seen as "homework tasks", differentiated teaching for students' range of abilities, allowing the "pausing and rewinding" of teachers in recorded presentations, increased student-teacher interaction, informed parents, a more transparent classroom, greater student motivation and interest, and improved classroom management (Bergman & Sams, 2012). In terms of student achievement, Hamdan et al. (2013) suggest that there has been little rigorous empirical research into this area, but their review documents three case studies in which improvements in student outcomes were attributed to the flipped classroom model. In Minnesota's Byron High School, for example, in 2011 nearly 75% of students passed the state maths test which was more than double the performance from three years earlier. Within their own school assessment, Byron High School reported an increase of 13.6% in calculus proficiencies, an increase of 11.3% in pre-calculus proficiencies and an increase of 12.8% in algebra and trigonometry proficiencies which they attribute to the flipped classroom approach (Byron High School Mathematics Department, 2014).

Teachers using the flipped classroom approach typically combine their own created online tutorials with those readily accessible online through sites such as *YouTube* and

Khan Academy. Again there is little research into the benefits or otherwise of using such resources, but a report on the *BlendMyLearning Project* (Greenberg, Medlock, & Stephens, 2011) found that through utilising the data available on students through the *Khan Academy* website, teachers were able to give students targeted, personalised attention when they needed it and on the topic in which they were struggling. Teachers also observed students' increased sense of responsibility and greater opportunities for differentiation and peer collaboration. In terms of student participation, the results from the project interestingly indicated that students rarely watched the videos provided, turning more to their peers and the classroom teacher, than the linked *Khan Academy* video. This is consistent with Muir's findings (2013) where students in Grades 8 and 9 preferred to ask their teacher and friends for help in mathematics, rather than accessing the internet. Muir also found that students held mixed views about the usefulness of the *Khan Academy* clips and how they were presented. While some found the presenter easy to understand, others found the clips "too repetitive", and not always tailored to individual needs. Bergman and Sams (2012) expressed concern about the use of generic videos rather than teachers delivering their own class-specific instruction, and Hamdan et al. (2013) suggest that this latter approach is the ideal, while also acknowledging that some students may benefit from hearing an alternative presenter. To have teachers delivering their own purpose-made content, however, requires of teachers the technical knowledge to record material, and, if necessary, use appropriate technology in the recording environment to optimise teaching.

Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge, or TPACK (Koehler & Mishra, 2008), is a knowledge framework that builds on Shulman's (1987) identification of the different knowledge types required for teaching and describes how teachers' knowledge of technology and pedagogical content knowledge (PCK) interact to produce effective teaching with technology. Shulman (p. 8) defined PCK as "an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction". The TPACK framework is presented as three intersecting circles: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). PCK is included in the TPACK framework, as the intersection of CK and PK, and where this coincides with (TK), at the intersection of all three circles, we have TPACK. According to Koehler and Mishra, TPACK incorporates an understanding of the presentation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn in a technological environment; and knowledge of students' prior knowledge and theories of epistemology. In preparing online tutorials for students, then, it seems logical to expect that the teacher will require strong TPACK in order to capitalise on the technology available and to develop creative flexibility with using technology in constructive ways to teach content.

The Present Study

The focus of this study is to examine the perceptions of one teacher and his students, regarding the use of the flipped classroom in a senior secondary mathematics course. It will also consider some aspects of the role of TPACK in successfully implementing the flipped classroom model.

Methodology

The case study reported in this paper was part of a wider study which aimed to investigate students' sources for assistance in mathematics, including online resources, and then to further investigate how, why, and what online resources were being accessed across a range of grades and contexts. In previous reports from the larger study, the focus was on students' self-initiated use of resources from Grades 5-9, with particular evaluation of *Khan Academy* clips. In this case study, the class selected was a Grade 11 Mathematics Methods class from a large metropolitan secondary college in Tasmania, with the focus being on the online tutorials that were prepared by their teacher. Mathematics Methods is a senior secondary course, with the major themes being function study, calculus, and statistics. It is designed to prepare students for study at tertiary level in fields such as mathematics, science, and engineering, and is also taken as preparation for studies in Grade 12 Mathematics Specialised.

The teacher, Mr Smith (a pseudonym), was a fully qualified mathematics teacher, with over 20 years' classroom experience who had been teaching the course for several years. He had recently attended professional learning involving the flipped classroom and was trialling aspects of it with his Grade 11 classes in 2013. He was confident with the use of ICT and held a leadership position in this area within his school. The student participants were in Grade 11 (approximately 16 years of age); there were approximately 20 students in the class, and 10 participated in the study (six males and four females).

The procedure involved a teacher interview, and student completion of an online Qualtrics survey. The interview was conducted with the teacher approximately two weeks before the students were given the survey. It was audio-taped and took approximately 30 minutes. The survey contained 24 items, two of which required responses to sets of statements in a Likert format (see Table 1 for the statements relevant to this study). There was also provision for open-ended responses. The survey took approximately 20 minutes to complete and the researcher was present while the students completed it online.

Qualitative data from the surveys and interview were transcribed and manually coded. Codes were assigned through reference to the four pillars from Hamdan et al. (2013), and benefits to students as identified in the literature. In addition, during data analysis the coder (the first author) was open to emerging themes. The following section presents the results and discussion from the data, from the perspective of the teacher and then the students.

Results and Discussion

Teacher Perspective on the Flipped Classroom Approach

Mr Smith was motivated to initiate the flipped classroom approach after attending a conference earlier in the year in which teachers attested that their results had improved because of the increased time spent one-on-one with students. The nature of the course that he was teaching was also another factor influencing his decision to trial the flipped approach, since it was his view that:

> In a packed course like Maths Methods, if I can reduce the amount of time that I'm at the board by having these pre-recorded demonstrations then I think that we are going to get through the course quicker and it's just a different way of learning.

It seems he was ready for a shift in learning culture (Hamdan et al., 2013), in that he found himself being "frustrated at only having an hour and fifty minutes for a lesson and sometimes spending an hour on the board doing examples of different types".

His development of a flipped classroom occurred gradually over the course of the year, peaking in third and fourth terms when revision and exam preparation efforts were a key focus of work. In terms of the actual pragmatics of implementing his flipped classroom, Mr Smith prepared on-line demonstrations or "tutorials" on his iPad using an application called Doceri. He usually recorded two to three a week, with each demonstration varying in length from about five minutes to 15 minutes. These tutorials were uploaded into the school's information management system for students to access. He also recorded parts of some of his lessons and posted links to additional video clips accessible through YouTube and Khan Academy. Figure 1 shows a screen shot from a demonstration on parabolas. This particular clip was approximately 9 minutes long and showed how to complete an exam-style question from the textbook.

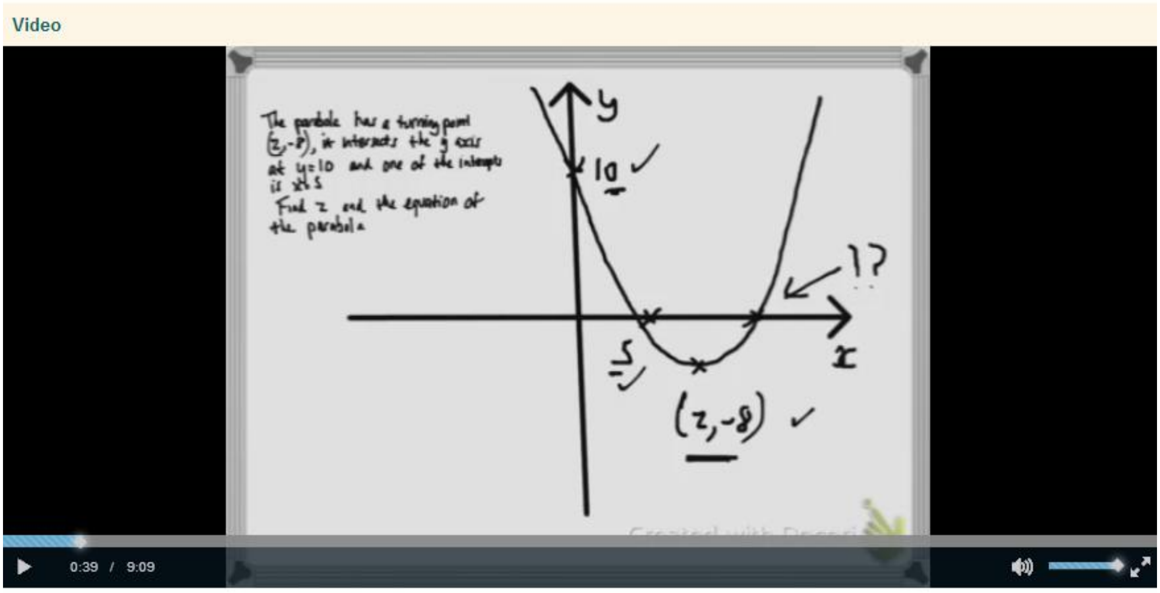

Figure 1. Screen shot showing demonstration of solving a problem about parabolas.

Recorded excerpts from the live lessons were also uploaded to the learning management system and they were available virtually instantaneously on completion of the live lesson. During class demonstrations he made use of the iPad and the Doceri application to project the image on the screen and recorded the image and his voice. He made the point that "you couldn't hear the students [on the recording], which was good because sometimes they give the wrong answers and they don't want to be embarrassed – if you hear them, it's very faintly, if at all." This use of recordings from live lessons suggests a hybridisation of the flipped classroom model, since he was recording material as he actually presented it to class. He explained that this was partly due to time pressures for preparing pre-recorded tutorials, but, possibly because of the high-stakes exam-based assessment involved in this course, he also acknowledged that his purpose with the live recordings was to provide revision material:

> … but also recording that so that if the students want to watch it in the evening or if they've been away, or during revision time if they want to revisit that topic – What did we do in that lesson? How did we teach that?— they've got that there as a record.

He acknowledged that he felt he was still doing too much whole class demonstration in the face-to-face class, rather than following a fully flipped approach:

> What I'd like to do is to limit the number of examples I have to do [in class] by just saying, right, your homework is not to be doing problems, your homework now is to view things and take notes from it so that when we come in the next day, OK I might do just one quick example just to get us going again but we can spend the majority of that time with you doing the work and me then going around and assisting.

Mr Smith's discussion of how he prepared the demonstrations and made them accessible to students indicated a high level of TPACK. He appeared to possess strong content knowledge about the actual subject matter being taught, along with technical knowledge (TK) that allowed him to recognise when technology could be used to assist in the achievement of a goal (Koehler & Mishra, 2008). Evidence of PCK was apparent through reference to choices of examples and anticipating student difficulties. For example, he stated:

> I tended to focus on the ones that they battled with the most – so I'd look at the ten questions that were set and I'd target say the five or six that you know were a bit difficult, and I did worked solutions of them on the video so they were able to pause that or go back or whatever. I still gave printed solutions as well, but once again, it saved time.

The above comment illustrates that it was likely that students would need to revisit the problems and solutions, and that technology provided Mr Smith with the avenue to cater for this. In addition, it also shows further evidence of a shift in learning culture from a teacher-directed to student-directed approach, together with providing intentional content (Hamdan et al., 2013).

In terms of gauging whether or not Mr Smith perceived the clips as being utilised and of benefit to the students, only anecdotal evidence was obtained. He indicated that the learning management system recorded student activity and he could see that "quite a number of my maths kids logged in so I'm assuming they're watching those things. I know they were well used during revision time to revisit". He perceived the main benefit to students was that he could maximise one-on-one time spent with them in class and that their learning was more focused, self-directed, and individualised.

When asked to compare his clips with the *Khan Academy* examples, he compared them favourably, stating that "they [*Khan Academy*] may have been better planned than me … but I suppose the difference is it's me, their teacher, doing it".

Student Perspectives on the Flipped Classroom Approach

The first part of the survey was designed to gain an overall picture of students' use of the internet and online resources in general. All students who completed the survey had access to a computer and internet at home. The data collected from the survey particularly relevant to this paper concern the students' reactions to Likert scale items about their use of the teacher-prepared tutorials. Table 1 shows the level of agreement or otherwise to these items; levels of agreement from the original five point scale have been collapsed. Although the number of respondents was small, the results have been expressed as percentages for ease of interpretation and comparison.

The table shows that all participating students agreed that the teacher-prepared tutorials helped them to understand a topic, were about the right length, and impacted upon their success in tests. The data indicate that overall students were positive about the use of the tutorials, with the greatest variation being in the response to watching the videos from beginning to end. When asked about the degree to which the tutorials were accessed, the following comments are illustrative of the typical usage:

> I accessed anything that I wanted more information on, or if I wanted help into how to do something. If I missed a lesson I was able to view what we learnt, and before a test I was able to revise the process.
>
> I would click on the video to watch and then take notes in my book … I always watched them from beginning to end because I didn't want to miss out on anything … some people might not do that because they think they understand it enough without having to watch it.

Table 1
Students' Responses to Likert Scale Items (n=10)

Statement	SA/A	Unsure	D/SD
The tutorial helped me to understand a concept	100%	0%	0%
The tutorial was about the right length	100%	0%	0%
I watched all of the tutorial from beginning to end	40%	30%	30%
I found the tutorial helpful	90%	10%	0%
I found the tutorial boring	10%	30%	60%
I think I did better in the test because I watched the tutorial	100%	0%	0%
I think I understood the work better in class because I watched the tutorial	90%	10%	0%
I used the tutorial to explore mathematics of my own	60%	20%	20%
I used the tutorial to explore ideas about mathematics begun in class	50%	40%	10%
I used the tutorials as a last resort because I was stuck on a problem	50%	20%	30%

Students indicated that although they did access other online tutorials (usually when directed), perhaps not surprisingly they preferred the teacher's demonstrations. This reflects Mr Smith's own view (reported earlier) about the personal connection students might make to him as their teacher, and echoes the points made by Hamdan et al. (2013) about the ideal of using the teacher as presenter. The students' reactions included: "I preferred Mr Smith's tutorials as they were explained well and easy to understand" and "they were suited to what we needed".

All students agreed that they would recommend the use of teacher-prepared tutorials to others, with the following response being illustrative of the reasons given:

> Yes definitely. It is a magnificent opportunity that we have, to be able to watch and listen to problems being evaluated. It was the best exam revision I found.

The students' perspectives indicated that they appreciated the flexible learning environment and that they were prepared to accept a shift in learning culture (Hamdan et al., 2013). In terms of benefit, most related it to accessibility, relevance, and improving learning, especially opportunities for revision.

Conclusions and Implications

While acknowledging the limitations associated with the study of one small case, including the fact that it was not possible to examine actual outcomes in terms of student performance, the results from the interview and surveys do indicate that the flipped classroom approach may be one way to address the teaching of a pre-tertiary mathematics class. The students appeared to find the recorded material helpful, although it was not investigated whether they perceived or experienced the kind of in-class interactions that proponents of flipped classroom advocate. Indeed Mr Smith acknowledges that he is in the process of changing his practice from a teacher-directed approach—where he spent the majority of class time demonstrating worked problems on the board—to one where classroom time was more targeted and often focused on one-on-one tutoring. Due to the amount of content that needs to be covered in the course, the associated time constraints, and externally imposed assessment measures, it seems that the flipped classroom can provide additional support to students. This has particular implications for other senior secondary mathematics teachers who, like Mr Smith, have found themselves frustrated at not capitalising on the limited class time available. The data highlight that the approach taken so far appears to emphasise students developing the capacity to tackle standard exercises, perhaps reflecting the exam-based assessment. It will be important to investigate further more complete implementations of the flipped classroom, especially to see if it might result in a shift to more interactive in-class discussions instead of an almost exclusive practising for fluency that may be a hallmark of this course.

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