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Flipping the Mathematics Classroom: Affordances and Motivating Factors

Tracey Muir
University of Tasmania

Abstract: Secondary mathematics teachers are required to contend with a number of challenges including motivating students to engage with mathematics, covering the prescribed curriculum, differentiating the content for a range of learners, and preparing students for further study and externally imposed assessment tasks. The flipped classroom offers an approach to teaching that can be used to address these challenges, with its autonomous nature being particularly applicable to mastery learning. This study investigates the characteristics of a flipped classroom and its impact upon students' motivations for engaging with mathematical course content in two different secondary mathematics classes. The findings suggest that the flipped classroom has a number of affordances which address students' needs for competence, autonomy and relatedness, particularly when enacted within a mastery paradigm.

Keywords: Flipped classroom, motivation, senior secondary mathematics, mastery learning

Introduction

Flipped classroom approaches are characterised by a change in the use of classroom and out-of-class time where activities traditionally considered as in-class work are completed out of class. Traditionally the domain of tertiary education, the flipped classroom approach is gaining popularity in secondary classrooms, particularly in the mathematics and science domains. The flipped classroom model that has been adopted in school classrooms has been largely attributed to Bergman and Sams (2012) who used digital technologies to record their chemistry lectures and demonstrations for students to access wherever and whenever it was convenient. The accessibility and affordances of digital technologies have facilitated the uptake of the approach, through allowing teachers to record and narrate screenshots of worked mathematical

problems, create videos of themselves teaching, or curate video lessons from internet sites such as Khan Academy[5] (Hamdan, McKnight, McKnight, & Arfstrom, 2013). While enactments of the flipped classroom approach varies among classrooms, typically the more routine aspects of instruction are moved from the classroom for students to access independently, usually through the use of videos, which may or may not be created by the classroom teacher. Class time can then be optimised with more targeted and individual instruction replacing or minimising whole class teaching. The reduction in time spent on in-class explanations and demonstrations provides the teacher with more time to devote to individual students, including helping them to develop procedural fluency (Hamdan, et al., 2013). Benefits of the approach include differentiation of learning for a range of students' abilities (Herreid & Schiller, 2013), greater transparency for students in relation to learning intent, and greater opportunity for teachers to be aware of students' progress (Bergman & Sams, 2012).

The success or otherwise of the flipped classroom, however, has not been extensively researched and subsequently remains under-theorised (Abeysekera & Dawson, 2015). The findings from the limited research that has been conducted, however, shows that the approach has merit, with identified benefits including increases in student achievement, success, engagement (e.g., Hamdan et al. 2013) and positive affective outcomes for students (Muir & Chick, 2014). The link with affective outcomes and student engagement is an important one as there is continued concern in Australia and internationally over the lowering levels of engagement with mathematics (Attard, 2010). Middle school students' attitudes towards, and interest in, science and mathematics continues to decline (Department of Education and Early Childhood Development, 2009) leading to less uptake of courses requiring specific levels of mathematics. Motivating students to engage with mathematics can be challenging, but instilling a sense of competence, relatedness and autonomy in students has been linked with increasing extrinsic and intrinsic motivation (Abeysekera & Dawson, 2015). The flipped classroom has been associated with these motivational factors, and is worth considering as an alternative to traditional mathematics teaching, which some students view as irrelevant and difficult to understand (Beswick, Muir, Jade, Farrington, & Callingham, 2013).

[5] Online education website: www.khanacademy.org

The study documented in this paper investigated students' and teachers' experiences and perceptions of the benefits or otherwise of flipping the classroom within the context of secondary/senior mathematics classrooms. The paper specifically reports on two different classes taught by two different teachers who were using a mastery approach to flipping their mathematics classrooms. In addition, this paper also describes a theoretical framework that was informed by findings from the literature and the study. In doing this, the paper addresses the following research questions:

- What are the characteristics of a flipped classroom approach which motivate students to engage with mathematics course content?
- What are the features of a motivational framework that can be used to interpret these characteristics?

While classroom observations were undertaken in order for the researcher to fully understand the enactment of the approach, the focus of the research was on the participants' perceptions of their experiences and the relative affordances or otherwise of the approach.

Theoretical Framework

Flipped learning and mastery

Currently the terms 'flipped classroom', 'inverted classroom' and 'flipped learning' appear to be used interchangeably in the literature, but a flipped classroom does not necessarily mean flipped learning. There are different interpretations of the approach and associated variations in implementation strategies, with flipped learning and mastery of topics being the ultimate goal. According to Bergmann, et al. (2013), flipped learning allows students to achieve mastery of topics as they are able to self-pace their learning. The ultimate aim is for students to access video resources when ready, work through the resources at their own pace, and demonstrate mastery through the completion of assessment tasks. While definitions and adoptions of mastery learning vary, essentially mastery learning theory is based on the belief that all students can learn when provided with conditions that are appropriate for their learning (Guskey & Gates, 1986). The adoption of mastery learning in this context could be described as "individually based and student paced" (Guskey & Gates, 1986, p. 74), in that students generally work at their own pace, independently of their peers, and move on to new material when they have demonstrated mastery of the current material. For consistency

throughout this paper the term 'flipped classroom' will incorporate all enactments of the approach, ranging from the use of pre-reading, and use of supplementary videos to full mastery. The teachers in the study discussed in this paper used the term 'flipped classroom' to describe their practice, which primarily utilised a mastery approach. This is in contrast to other approaches, particularly those utilised in tertiary settings, whereby students may be expected to complete set tasks (which may include watching videos) before attending class, with class work being directed at the whole class, who are essentially working at the same pace.

The affordances of flipped learning

The term 'affordances' is often used in mathematics education to describe "a potential for action, the capacity of an environment or object to enable the intentions of the student within a particular problem situation (Tanner & Jones, 2000, p. 78). Affordances provide for allowable actions to occur between an 'object' and 'actor' (Gibson, 1977, p. 78) but the existence of an affordance does not necessarily imply that activity will occur.

Studies in the literature which identify the benefits or affordances of flipped learning tend to be dominated by tertiary contexts (e.g., Ford, 2015; Herreid & Schiller, 2013; Strayer, 2012). However, a small number of studies have focused on the use of the approach in secondary mathematics classes (e.g., Straw, Quinlan, Harland, & Walker, 2015) and have identified similar affordances. Straw et al., (2015), for example, investigated how flipped learning could be developed in UK mathematics classes, using Khan Academy resources (rather than teacher created resources). Teachers reported a number of impacts upon teaching and learning practices and students' engagement, learning and skills. These included more time for practising and applying knowledge and skills, questioning and higher level discussions, collaborative learning, independent and student-led learning, individualised support and increased understanding of students' learning styles. They also reported that students showed increases in engagement in learning, knowledge and understanding, confidence, awareness of strengths and weaknesses, independent learning skills, and progress and attainment. Challenges identified included identification of appropriate online resources, access to technology, students not participating in preliminary homework and teacher and/or students' preference for face-to-face as opposed to remote instruction.

In some cases the challenges were overcome, while in others, particular challenges limited the impact achieved.

While Straw et al.'s (2015) study did not involve teacher creation of the resources, as recommended by Bergmann and Sams (2012), Clark's (2015) study investigated ninth-grade students' engagement with the flipped classroom approach which included teacher created videos, along with podcasts, reading of articles and viewing presentations. Students reported increases in classroom participation, active engagement and learning, better use of class time. They also felt that the use of technology and one-on-one teaching in the flipped model of instruction enhanced the quality of instruction (Clark, 2015). Overall the students were very positive about their experiences, with the only concern raised being the actual unit content selected for instruction was particularly challenging (which may have accounted for similar performance results).

The author's own studies showed students' overall satisfaction with the approach. For example, in a study conducted by Muir and Geiger (2015), survey responses from a Grade 10 mathematics class showed that 93% agreed that online resources were helpful to their learning and 100% agreed that they found the tutorial helpful. The majority of students agreed that they performed better in tests as a result of watching the tutorial and there was 100% agreement that they understood the work better, indicating students believed the videos were supportive of their development of mathematical competence (Muir & Geiger, 2015). Muir (2016) also found that in contrast with traditional teaching practices experienced in the past, students found the video tutorials prepared by their teachers to be relevant, engaged their attention, provided for greater autonomy over their learning and enabled them to attain their goal of mastery over their learning.

Self-efficacy, motivation and the flipped classroom

Self-efficacy, as defined by Bandura (1986, p. 391), refers to "people's judgements of their capabilities to organise and execute course of action required to attain designated types of performances". Schunk (1991) refers to self-efficacy as an individual's judgements of his or her capabilities to perform given actions and describes efficacy appraisal as an "inferential process in which persons weigh and combine … personal and situational factors [such] as their perceived ability, the difficulty of the task, amount of effort expended,

amount of external assistance received, number and pattern of successes and failures, their perceived similarity to models, and persuader credibility (Schunk, 1991, p. 208). Personal factors such as goal-setting, information processing, and perceived control can influence an individual's motivation to engage with a task. Motivation has been defined as "the willingness to attend and learn material in a developmental program" (Cole, Feild, & Harris, 2004, p. 67). While ability and intellect influence what students can do, Cole et al., (2004), contend that it is the level of motivation that influences the amount of focus and effort students will exert on a given learning activity. Students' levels of motivation can be seen as an outcome of their learning environment which can either promote or impede the satisfaction of their basic cognitive needs (Deci & Ryan, 2008). Deci and Ryan (2008) in their Self – Determination Theory (SDT) identified three basic cognitive needs to be satisfied: competence, autonomy and relatedness. According to Ryan and Deci (2000), intrinsic motivation (a natural inclination toward assimilation, mastery, spontaneous interest, and exploration), is catalyzed when conditions such as competence, autonomy and relatedness are present. These factors which form a sub-set of SDT, Cognitive Evaluation Theory (CET), are linked with studies showing that feelings of competence will not enhance intrinsic motivation unless accompanied by a sense of autonomy or, in "attributional terms, by an internal perceived locus of causality" (Ryan & Deci, 2000, p. 70). Relatedness is another factor which can produce variability in intrinsic motivation (Ryan & Deci, 2000). This relatedness does not dictate a close proximity, given that many intrinsically motivated behaviours are performed individually (Deci & Ryan, 2000), but a secure relational base does seem important for enhancing motivation.

Abeysekera and Dawson (2015) developed a framework that incorporated Ryan and Deci's (2000) motivational factors of competence, autonomy and relatedness and combined them with tailoring to expertise and self-pacing (see Figure 1). They argue that tertiary students' basic cognitive needs can be satisfied through a flipped classroom approach, leading to improvement in student motivation if it creates a sense of competence, autonomy and relatedness. In their theoretical model, students develop a sense of competency through a belief that they can perform a task, are motivated to perform the task if they can relate to it as being important and interesting, and are more likely to complete the task if they have a sense of autonomy or belief that they are responsible for their own learning. These factors can theoretically lead to

increased extrinsic and/or intrinsic motivation. Two other elements identified in the framework: 'tailoring to expertise' and 'self-pacing', theoretically lead to better management of cognitive load. The authors argued, for example, that encouraging students to manipulate the pace of the videos may result in gains in learning as learner pacing can help manage cognitive load. The framework was developed within a higher education framework and was untested by the authors in the paper. Instead, they called for research studies to empirically test the propositions made. The research discussed in this paper answers that call through reporting on qualitative data, documenting student experiences of the flipped classroom approach. It builds on previous work through expanding and adapting the motivational aspects of Abeysekera and Dawson's (2015) original framework and applying it to two secondary mathematics contexts where the teachers were using a mastery approach to flipping mathematics lessons. The adapted framework aligns the characteristics identified by the participants with the relevant components of Abeysekera and Dawson's (2015) framework through re-conceptualising students' motivational factors and situating them within the motivational factors identified by Ryan and Deci (2000). The newly developed framework (see Table 1) is fully described in the next section 3.4 and addresses the second research question.

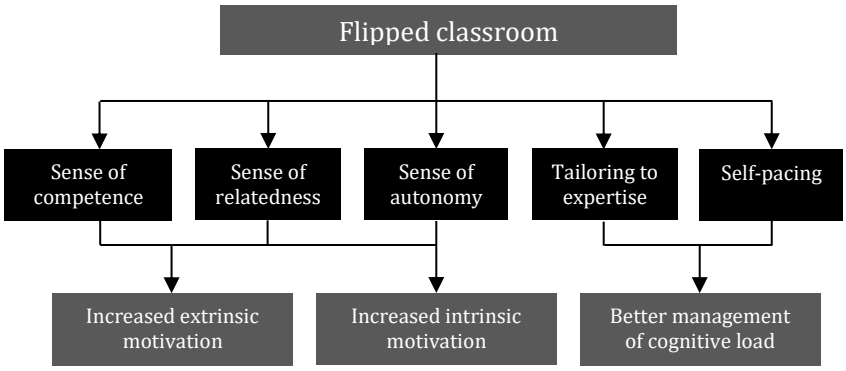

Figure 1. Theoretical model for the flipped classroom (Abeysekera & Dawson, 2015)

Method

Context and overview of the study

The research reported in this paper was part of a larger study which employed a mixed-methods approach (Creswell, 2003) to investigate the affordances of a flipped classroom approach in 10 senior secondary mathematics classes. Participating students completed online surveys containing a mix of Likert items and open-ended questions, classroom observations were undertaken and interviews were conducted with teachers and students. Consistent with mixed-methods methodology, items and responses from the survey were used to inform the semi-structured interview schedule, however as the Likert-scale items from the survey were not validated, only open-ended responses from the survey (along with the interview and observation data) are reported on in this paper. Full ethical approval from all jurisdictions was granted for the research.

The cases reported on in this paper involved two classes where the teachers were flipping their mathematics classes using a mastery approach. In both cases, the teachers created their own bank of video tutorials that were available for access from the respective schools' learning management systems. The students would view the tutorials out of class, complete individual work from the prescribed text in class, sit a test to demonstrate mastery of a topic and then move on to the next topic.

Participants

The participants were Mr Hill[6], a fully qualified mathematics and science teacher, who had been flipping his mathematics class for three years and his class of 27 Grade 10 mathematics students. The second class, consisting of nine Grade 12 students, was a Specialist Mathematics class[7], taught by Mr Burns. Mr Burns was also a fully qualified mathematics teacher, with over 20 years of teaching experience. This was his first year of flipping the classroom, and at the time of the study he had created approximately 193 video tutorials for the students to access which covered the requirements of the course.

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[6] Pseudonyms used for schools and participants throughout

[7] Specialist Mathematics is considered the most advanced mathematics course in High School and includes topics such as conic sections, complex numbers, differential equations, kinematics, vector calculus and mechanics.

Instruments and procedure

Data collection instruments consisted of an online survey using Qualtrics[8], semi-structured student and teacher interviews, and classroom observations. Open-ended responses to items 5, 15 and 23, in the survey asked students to list the advantages of using online resources instead of the textbook or asking their teacher, and whether or not they would recommend the videos to others and why are reported on in this paper. The student semi-structured interviews were designed to allow the researcher to probe more deeply into the students' experiences of the flipped classroom as reported through the survey (see Appendix 1 for interview schedule). The teacher interview schedule (see Appendix 2) was designed to elicit information about the teachers' motivation for implementing the flipped classroom approach, how it was enacted in practice and their perceptions of the benefits and challenges of incorporating the approach. Classroom observations were used to triangulate the data collected from the surveys and interviews and enabled the researcher to see how the approach was enacted in each classroom. As the focus of the research was to identify the characteristics of the approach from the teachers' and students' perspectives, the classroom observations are not explicitly reported on in this paper.

Thirty-six students provided responses to the open-ended survey prompts, and six students were interviewed from each class, which resulted in a total of six focus group interviews, conducted with 2-3 students in each group. The interviews were audio-recorded and transcribed and took approximately 20-30 minutes. The teacher interviews were conducted individually, prior to the classroom observations and student interviews. They were also audio-recorded and transcribed and took approximately 40 minutes each.

Data analysis

Qualitative data from the surveys and interviews were analysed using reflexive iteration (Srivastava, 2009) whereby each sentence in the transcripts was coded using open themes that emerged from the data. This was done to ameliorate any researcher bias that may have occurred if only the pre-conceived themes from Abeysekera and Dawson's (2015) framework were used. The transcripts were then re-read to identify instances of the components identified in Abeysekera and Dawson's (2015) framework, with codes being

[8] An online survey construction tool: http://www.qualtrics.com/

clustered into the categories as identified in Figure 1. For example, reference to 'convenience' or 'easily accessible' were assigned to 'sense of autonomy' because the comments indicated that students could access the resources where and when they were required. While this worked to some extent, it became evident that there were multiple references to some aspects that indicated that a sub-category would better capture the essence of the comment. Furthermore, it seemed that responses from students and teachers were either related to their motivation for engaging with the resources, or commenting on the affordances of the approach. While acknowledging that these elements are linked and influence each other, the distinction was important as the affordances could not be accessed if the students were not motivated to engage with the resources in the first place. The researcher was interested, therefore, in what motivated students to access the video tutorials, and then once accessed, did they perceive them as being beneficial to their learning?

Abeysekera and Dawson's (2015) framework was limited in terms of distinguishing these factors and the all-encompassing aspect of their components proved restrictive in terms of reporting accurately on the themes that emerged from the participants' data. It was therefore necessary to add sub-categories to Abeysekera and Dawson's (2015) original three motivational components (see Table 1), including the sub-category of self-pacing, which, in the original framework, was a contributor to management of cognitive load. From an analysis of the interview data obtained from both the teachers and the students, this seemed to be a contributing motivational factor for accessing the videos. In terms of identifying sub-categories, for example, there were a number of references to relevance, and this seemed a strong motivator that worked with other aspects such as preparedness, goal attainment, capacity to focus and priming, to contribute to a 'sense of competence'. Self-pacing was an example of a sub-category which related to developing a 'sense of autonomy'. The categories were not mutually exclusive, in that some phrases referred to more than one aspect; for example, students may have referred to the videos being relevant because their teacher prepared them, which was coded as 'relevant' and 'relatedness'. As another illustrative example, the comment, "They are allowed to move ahead, they can go any speed they want" [Mr Burns] was coded as being 'self-pacing' and 'differentiation'.

Table 1 provides an overview of the description of each sub-component as it contributed to the three motivational components in Abeysekera and

Dawson's (2015) framework. The components in the table highlight the factors that contribute to developing a sense of competence, a sense of relatedness and a sense of autonomy in students – all of which influence students' intrinsic and extrinsic motivation to engage with the flipped classroom approach. The description of the individual sub-components also highlight particular characteristics of the approach in contrast to more traditional teaching methods. In this context, more traditional methods refers to the students' experiences of mathematics teaching in the past, which typically involved whole class teacher instruction and demonstration and completing homework exercises from a prescribed textbook.

Table 1
Description of motivational components and sub-components

Abeysekera & Dawson's (2015) components	*Sub-components*	*Description*
Sense of competence	*Preparedness*	*Prepared for class, in terms of familiarisation with content and provision of knowledge of what to expect in class*
	Relevance	*Material should be directly applicable and relevant to course studied*
	Goal attainment	*Closely aligned with 'relevance'; material must allow students to achieve learning goals and success*
	Capacity to focus	*Less likely to be distracted by external factors, such as other students in class; allows for revisiting of content*

	Priming	*Element of self-directed learning; refers to familiarisation with material before being introduced to it in class; encourages activation of prior knowledge*
Sense of relatedness	*Relatedness*	*Refers to students' capacity to relate both to the content of the video, and the presenter*
	Captivation	*Refers to the inherent appeal of the resource and its capacity to engage students and maintain their attention*
Sense of autonomy	*Autonomy*	*Feeling of taking responsibility for own learning; links with self-pacing*
	Convenience and accessibility	*Course content accessible anytime and anywhere; access for absent students; ongoing resource*
	Differentiation	*Students access videos that are relevant to their progress in the course; teacher provides range of materials to cater for diverse learners*

	Self-pacing	*Includes the practice of pausing and rewinding the video while viewing, and working individually through the course content*

Results and Discussion

This section presents the results and discussion from the data gathered primarily from the students and their teachers, organized around the themes that were identified in Table 1.

Motivational factors

In the survey and the interviews the students were asked to identify any advantages of online resources over the use of a textbook or asking the teacher, how and why they used the resources, whether or not they would recommend the resources to others and how the approach compared with their past experiences of mathematics lessons and homework. Illustrative responses have been provided to demonstrate reference to the components identified in Table 1.

Sense of competence

Goal attainment was the dominant motivational factor, probably attributable to the mastery adoption of the flipped classroom approach by both teachers. Students reported that the videos helped them understand the content which enabled them to pass the tests, leading to success in the subject and ultimately access to further study. The following comments are illustrative of the responses received (quotes italicised throughout):

I want to pursue maths in college and university and just the fact that it gives you a wider view of it and dives into the deeper understanding of topics such as calculus, number functions and stuff. At the start I didn't realise that it was actually video tutorials but once I did the first couple of lessons where I was a bit shaky, but then it got really easy and I'm going a lot better in maths this year than I did last year. [Jack, Grade 10]

I feel more motivated now definitely than I was last year, now I am striving to achieve, I'm always trying to get that A every test. [Matt, Grade 10]

Yeah because like a lot of things, I wouldn't understand like for example linear relations, I wouldn't understand why that was beneficial to a lot of things but when I understood the proof behind it and the reason for doing so which he provided in a lot of the videos, it was much more relatable, I had a better understanding of what it's really all about. [Lee, Grade 10]

It was also important that the tutorials were *relevant* – this was a strong theme in both the student and teacher interview data:

… He would have spent a lot of time making those videos - he sets out exactly what's going to be needed for the test so um he'll go through the text book, figure out which exercises he'll go from say questions 3 to 7 because he doesn't think 2 or 8 are going to be of any benefit, he'll just direct it straight to the questions he'll go over in the theory and you should be able to do. Even if it's a follow on where you have to get some sort of other theory to bring in, he'll always resemble the questions around that theory.

[Lee, Grade 10]

The students relate I think better than they do to somebody talking about a video that may contain 40 or 50% of what they are looking for; the videos they are looking at now contain 100% of what they are looking for so it's more important in that respect. [Mr Burns]

While some enactments of the flipped classroom approach involve access to curated videos prepared by others, the highly specified nature of the courses being taught by both teachers really required the videos to be tailor made. Not only did this have the advantage of students being able to clarify aspects they might not have understood with the teacher in class the next day, the students were also confident that their teachers were providing them with accurate and relevant information in order to pass assessment tasks.

While most students generally believed that it was important that the teacher produced the videos, others felt that it was not essential, if the content was perceived as being *relevant*. Liam, for example, believed that it was helpful that his teacher prepared the videos, but not essential:

It wouldn't make that much difference if it was a different teacher. I think the one thing that would make a lot of difference is the fact that if he's not doing it and he's not setting out the videos then … we can't ask him, oh how did you go about doing that, how did you do this um, what's the method behind this ... but it wouldn't make too much difference in the side of understanding the theory. [Lee, Grade 10]

Bergman and Sams (2012), however, advocate the importance of the teacher preparing the videos and this was confirmed in earlier studies by Muir (2015) and Muir and Geiger (2015). According to Bergman, "If you can be replaced by a YouTube clip, then you should be" (J. Bergman, personal communication, August 21st, 2015), implying that the teacher should still maintain a vital role. Both teachers felt that it was important that they created the videos, both in terms of relevance and to foster a sense of *relatedness (*discussed further on). Preparing the videos also provided for reflection upon their delivery of particular content and enabled them to ensure classroom based experiences complemented, extended or consolidated the learning of content introduced in the videos.

Preparedness was another motivational factor identified from student and teacher data. Some students were motivated to access the videos because they wanted to be prepared for class, either in terms of understanding the content in order to achieve their goal, to remove uncertainty and anxiety about what would happen in class the next day, and to avoid *"being embarrassed in front of your friends"* [Liam, Grade 10]. The teachers also thought this was an important motivator, with Mr Hill commenting, for example, that:

… Like I used to get annoyed um when you'd pass a kid in the playground and they'd say, Mr Hill what are we doing in maths today? I'm like, just wait for maths and I'll tell you when I get there – I don't want to explain it to 20 kids on the way to the staff room but then I thought that kid's telling me they're engaged … after I thought how would I feel if the Principal said OK, there's a PD staff meeting for an hour after school today, we'll see you there – straight away, I'd be like what's it about? What are we doing? What do I need to bring? And it would kind of stress me and I think well that's how the students feel. [Mr Hill]

Preparedness also helped to develop students' sense of competency through enabling them to prime the content before coming to class. In this study, priming was not a major theme identified in the results as students were working individually using a mastery approach. Students did feel, however, that it was more beneficial to watch the videos prior to class, rather than watching the videos after attending class:

Yes definitely because then you're not going off having missed 5 equations you were meant to write down. [Antony, Grade 10]

You might then have to waste your class time doing the rules and you don't get as much class time to do all the work. [James, Grade 12]

In other enactments of the flipped classroom where the teacher directs the pace of instruction and students work through the curriculum at the same pace, it would be anticipated that *priming* would likely be more of a perceived benefit. The students interviewed typically reported that accessing the videos individually out of class helped their *capacity to focus*, as they did not have to attend to distractions which are typically a part of whole class instruction:

A lot of people can't find time in their school day, they might be distracted by other kids, they might not think learning's cool so they don't do everything at school but at home, they are by themselves and they don't need to worry about any other distractions, they can just do it.

[Lee, Grade 10]

There's no interruptions [at home] whereas in class there are so many interruptions … he might be halfway through an explanation and then somebody interrupts … if you get distracted, [at home] you just pause the video and come back to it. [Chris, Grade 12]

[in regard to last year] you would be sitting there and watching the teacher and might get a little bit bored, you might not remember every single little bit of it and then you would have to go and to try and re-learn it and the teacher gets frustrated at you for not listening and then it gets worse and worse and you fall behind. [James, Grade 12]

The students' comments in relation to this aspect particularly highlight the motivational aspects of the flipped classroom in contrast to more traditional

approaches, and its potential for developing a sense of competence, not just in themselves, but for other students as well.

Sense of relatedness

While some of the students downplayed the role of the teacher in terms of relevance, it was obvious that in both classes there was a strong rapport between the students and their teacher. In Mr Burns' case, he felt that the flipped classroom approach actually enhanced the teacher-student relationship:

The one thing I really like about the flip classroom is the close proximity I've come with my students … I think it's very important … because you still need that teacher/student relationship and that works for the student and that works for the teacher. I can give them 20 or 30 videos to look at on a particular topic that are on YouTube but whether they'll get anything out of it compared to having me do the video and talking about them at their level … I know who they are and what they're doing, I think makes a big difference. I think it really is important that the teacher does the video, it really is.

[Mr Burns]

The results supported Abeysekera and Dawson's (2015) proposition that flipped learning environments are likely to satisfy students' need for relatedness and thus entice greater levels of extrinsic motivation. The results also indicated that in this study it seemed that the relationship with the teacher actually acted as a motivator in its own right. Students appreciated the effort and time that went into creating the videos and virtually felt obligated to watch them as a result of this.

Closely linked with this was students' appreciation of their teachers' efforts to make the videos 'entertaining', hence attending to the motivational factor of *captivation*. The term 'captivation' rather than 'interest' was used to classify these comments as 'interest' has its own construct (e.g., Hidi & Renninger, 2006), and students were not necessarily inherently 'interested' in the content of the videos. The teachers were cognisant of the need to not only make the video tutorials *relevant,* but captivating as well. This included limiting the videos to ten minutes and including jokes and anecdotes.

Mr Hill brings a sort of enthusiasm with these videos and he just brings it across and like explains it very well. [Jack, Grade 10]

He [Mr Burns] kind of comes down to our level at times which is really good … he will have a joke as well … like with the factor of ten and he got the people from the horticulture thing to bring a goat so the G factor of ten is related to a goat then he got the goat to bleat … [James, Grade 12]

Sense of autonomy

Students appreciated that the flipped learning approach provided an alternative to the mathematics teaching they had experienced in the past and enabled them to exercise control over their learning – not just at home, but also in class:

Like if he's up at the board having to do theory for half the lesson like then you've only got another 30 minutes to go around 26 students and try and figure out what they've gone wrong. [Jack, Grade 10]

The following comment from Mr Hill illustrates how class time was maximised to cater for individuals who were able to self-pace their learning:

The kids are really into this system now – I have my whiteboard markers sitting next to me and kids will just generally walk up, and say do you mind if I just grab a marker, and they'll start working on the board and then when they're ready, like when they're at a point when they're stuck, they'll say Mr Hill, I've done this – where do I go from here? And I'll come up and show them and work them through it. [Mr Hill, Grade 10]

These comments and the ones that follow, illustrate a contrast with how these students experienced mathematics teaching in the past. It highlights that the teacher's role in a flipped classroom that is using a mastery approach is one of a facilitator rather than an instructor. Working within the mastery approach enabled the learning to become more individualised and *differentiated* for the students, facilitating *self-pacing* and thereby further fostering a sense of *autonomy*:

Yeah, that's good because we've gone ahead [unlike last year when] we've been distracted by a teacher teaching in a class whereas in here we can work

wherever we are whether you're behind or if you're ahead or if you're on time. [Cameron, Grade 12]

He leaves it up to you –it just I guess lets you experience independent study … you could pretty much be away for all the in class lessons but do it at home and then you come for the test day and still be prepared.

[Jock, Grade 10]

[In the past] I'm thinking when are we ever going to get through this curriculum? I don't have that worry at all with these kids. [Mr Burns]

Mr Burns also recognised that an important affordance of the flipped classroom approach was the facility for students to *self-pace* through literally pausing and rewinding the videos:

A couple of months ago … one of the girls in the class came to me and she said … I've got to watch those videos 3 or 4 times before I understand what's going on and I thought to myself, gee I only teach it once and if I only taught it once, she wouldn't have got it. [Mr Burns]

The *accessibility* of the videos facilitated a sense of autonomy in that it enabled students to choose when they wanted to learn the content and thus enabled them to focus more on the content being delivered. The *accessibility* of the resources also catered for absent students:

If you're away you can just do it at home because it's all there.

[Jack, Grade 10]

I recently had a trip to Indonesia and I did all my maths over there as well and when I got back I had a test and I was up to date with everything.

[Lee, Grade 10]

Students also appreciated that *self-pacing* allowed them to work individually through the course content and demonstrate mastery:

[Last year] it's almost like sometimes like the teacher was disadvantaging us because we can't just go ahead [in class] 'cause we get told to be polite and [we have to] focus on what we already learnt and already know.

[Andrew, Grade 12]

One student in Mr Burns' class had actually finished the entire course content five weeks before the end of term and then utilised the remaining weeks to prepare for the external exam.

Conclusions and Implications

The results showed that there are a number of motivational factors and affordances offered by flipping senior secondary mathematics lessons. While acknowledging the limitations of reporting on two small case studies, the richness of the data gathered from the participants provided an insight into their perceptions of the benefits or otherwise of such an approach. While the researcher was open to participants identifying limitations or challenges of the approach, the results revealed that for these participants at least, they chose to focus on the affordances. It is also important to acknowledge that the teachers in the study were enthusiastic about the approach and that their students seemed particularly motivated, which may not always be the case, particularly with students who are disengaged with their schooling.

While Abeysekera and Dawson's (2015) framework proved to be a useful basis for interpreting both teachers' and students' perceptions in terms of identifying motivational factors for engaging with the flipped classroom approach, an expanded version of the framework as detailed in Table 1, provided for more specific characteristics to be included. *Goal attainment*, for example, was identified as a particularly strong motivator, with students appreciating that the approach created a sense of competence, which was particularly applicable in the context of preparation for externally imposed assessment tasks. In order to help students achieve their goal, the students identified that the prepared videos needed to be *relevant*, with this factor being more important than the resources being necessarily prepared by their class teacher. The teachers, however, believed that it was essential that the videos were prepared by them in order to tailor instruction particularly to students' needs. Students did, however, comment on the appeal of the videos and often made reference to their teachers' manner and personality. Although provision was made for it to occur, the students and teachers did not express any real concerns with the approach, other than acknowledging the initial time and resources required to produce the video tutorials. Challenges highlighted in

the literature, including students coming to class unprepared (Herreid & Schiller, 2013), access to technology (FLN, 2015; Straw et al., 2015), and resistance from students or parents (Straw et al., 2015), were not issues identified in this study.

This article adds to existing knowledge in three ways. Firstly, it has built upon Abeysekera and Dawson's (2015) framework that was developed within a tertiary context and applied it to a secondary classroom context. This application revealed that while the framework was relevant, there were particular characteristics or affordances identified by the participants that satisfied students' needs for autonomy, relatedness and competence. The identification of specific affordances provides practitioners with a rationale for adopting the approach and addresses some of the challenges involved in teaching senior secondary mathematics courses. Secondly, the author has demonstrated that the newly developed framework as described in Table 1, can be used to interpret the enactment of a flipped classroom, particularly within the context of using a mastery approach to teach senior secondary mathematics. While the approach may be transferable to other content areas, it seems particularly appropriate to senior secondary mathematics which is heavy in mathematical content, characterised by formulas and worked examples, and subject to externally imposed high stakes assessment measures. Finally, the rich data gathered through student and teacher interviews, and presented as case studies, provides insight into participants' experiences of this approach.

The study has a number of implications for teaching and learning practice. The study has practical implications for teachers who find it challenging to cover what seems to be an increasingly expanding curriculum and to prepare students for externally imposed assessment tasks. Through optimising class time, and creating a sense of *autonomy* through self-paced instruction, the flipped classroom can cater for those challenges. The approach also provides for individualisation, allowing teachers to *differentiate* the learning for a wide range of students' needs and abilities.

The study also has implications in terms of influencing homework practices. Studies have shown that homework tasks are often a source of tension between students and parents (e.g., Civil, 2006) and that parents are less able to assist as homework tasks, particularly in mathematics, become more challenging as

students move through school. This can lead to students accessing online resources that may or may not be credible sources of information. Having access to one's teacher via a video tutorial seems to be a preferable option for these students in comparison with completing exercises from a text book or seeking assistance from the internet.

While this study did not directly compare traditional teaching practices with a flipped classroom approach, the participants in the study often contrasted their current experiences with the ways they had experienced mathematics in the past. With regard to this, the findings indicated that the students in this study found the video tutorials prepared by their teachers to be relevant, captivating, allowed for greater autonomy over their learning and enabled them to attain their goal of mastery over their learning, which is not necessarily characteristic of many mathematics secondary classrooms. While the findings are promising, further studies are required to gauge the effectiveness of such an approach in different contexts with different cohorts of students. Further research also needs to be undertaken to investigate the impact of the flipped classroom on student outcomes as this was not explored in this study.

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Author:

Tracey Muir (tracey.muir@utas.edu.au), University of Tasmania, Faculty of Education, Locked Bag 1307, Launceston, Tasmania, Australia.

Appendix 1

Student Interview Schedule – Flipped Classroom

- Do you want to start by briefly describing to me what a typical maths lesson looks like in your class?
- How is that different from the maths lessons you have experienced in the past (last year and/or high school)?
- Do you access any online videos, tutorials or mathematics resources not prepared by your teacher? If so, can you describe these?
- If you were at home and you were trying to work through your mathematics homework and you couldn't do it, what would you do?
- Now focusing on the tutorials that your teacher prepared, about how many have you accessed this year?
- Can you talk about how that worked? Did he say you have to watch this before the next class, or these are there if you want to watch them? How did it work?
- When you were watching the videos at home, how did that work? Did you take notes? Did you watch them from beginning to end? Can you help me picture what you were doing at home?
- Did you then go back to class and ask him questions about what you viewed?
- What did you think of the maths videos that he produced? Is there anything about how he presented it that made it particularly effective? Was there anything about his teaching style that made it helpful and useful?
- Do you think it is important that your teacher prepares the videos or doesn't it matter?
- How do they compare with YouTube sourced videos?
- Do you think watching videos is an effective way to learn mathematics?
- Do you think homework is more engaging if it is the videos or working from the textbook?
- What aspects of teaching help you learn mathematics the most?
- Which method of delivery do you prefer – ones with no videos or one with videos?
- Do you think that it works better to watch the videos before class, or after class?
- What motivates you to watch the videos?
- How important is to you to be able to work at your own pace? (if relevant)
- Would you recommend this approach to other students? Other teachers?
- Do you think this would have 'worked' for when you were in earlier grades? Do you think it would work for earlier grades now?
- Anything else you would like to add?

Appendix 2

Teacher interview schedule – Flipped Classroom

- Background/context – classes taught
- What do you understand by the term flipped classroom?
- Would you say you are using the flipped classroom approach with your teaching?
- Describe how you use/prepare online tutorials.
- How do you give students access to them?
- How do you decide which examples to focus on?
- Do you make use of other resources, such as Khan Academy/Youtube?
- What was your motivation for using?
- Have you had any PL or been to PL/conferences where flipped classrooms have been discussed?
- Are other teachers in the school using it for mathematics or other subjects?
- Do you record sessions in class (e.g., on iPad) and upload those?
- How many do you think you have recorded this year? Can they be reused? Have you reused any from previous years?
- How many students do you think watch the tutorials at home? Do you do any tracking of this?
- Do you ever watch them yourself and perhaps reflect on how you explained things?
- How do you think they compare to something like Khan Academy or other online tutorials?
- How important do you think it is that their teacher is presenting the tutorials?
- In what ways, if any, has your classroom teaching changed as a result of using this approach?
- Would you go back to a more traditional way of delivery?
- What do you think have been the benefits for you? For your students?
- What have been the challenges or limitations?