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► To cite this version:

Theodosia Prodromou. Using a flipped classroom approach in the teaching of mathematics: A case study of a preservice teachers' class. CERME 10, Feb 2017, Dublin, Ireland. hal-01942126

HAL Id: hal-01942126

<https://hal.science/hal-01942126>

Submitted on 2 Dec 2018

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Using a flipped classroom approach in the teaching of mathematics: A case study of a preservice teachers' class

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This study investigates the usefulness of a flipped classroom approach in tertiary education. This exploratory study was conducted to understand the efficacy of the flipped classroom approach that was implemented by a lecturer teaching mathematics education. The study was conducted with the lecturer and her 185 pre-service teachers who attend her online course. Data collection instruments included a survey designed to investigate the dynamics of the flipped approach, semi-structured interviews for the pre-service teachers and the lecturer. The study adds to the literature related to the flipped classroom approach and the role of the lecturer in a flipped classroom.

Keywords: Digital technologies, flipped classroom, flipped learning, mathematics education, tertiary education

Introduction

The integration of digital technologies is becoming central in our mathematics classrooms. Some schools use digital technologies to replace or supplement teaching resources (Geiger, Goos, & Dole 2015). Multiple studies have been conducted that show that teachers and schools find it challenging to integrate such resources within mathematics lessons (Gueudet, Pepin, and Trouche 2012; Clark-Wilson, Robutti, and Sinclair 2014). Flipped classrooms integrate digital technologies allowing the teacher to implement the restructuring and re-organisation of teaching materials in both synchronous and asynchronous modes. The facilities of the classroom approach can be accessible from anywhere, in both real time or otherwise. How to best take advantage of digital technologies implemented in flipped classrooms is a challenge while attending at the same time to the dynamics of a flipped classroom and what is entailed in flipped learning. Given that research on the flipped classroom approach is in its infancy, there is limited research that has examined the approach under a pedagogical microscope.

Flipped classroom and flipped learning

Bergmann and Sams (2012) distinguished between the terms 'flipped classroom' and 'flipped learning', pointing out that they are not synonymous and that flipping the classroom does not necessarily lead to flipped learning (FLN 2014). There are different interpretations of this approach and associated variations in implementations strategies. According to Bergmann, Overmyer and Wilie (2013), the characteristics of flipped learning are:

- increased interaction and personalized contact time amongst students and teachers;
- students take responsibility for their own learning;
- the role of the teacher is not the 'sage on the stage', but the 'guide on the side';
- a blending of direct instruction with constructivist learning;
- students who are not able to attend the class due to illness or extra-curricular activities such as athletics or fieldtrips, don't get left behind;
- content is permanently achieved for review or remediation;

- all students are engaged in their learning;
- all students can receive a personalised education.

Abeysekera and Dawson (2015, p. 3) defined the following typical characteristics of a flipped classroom within higher-education settings:

- a change in use of classroom time;
- a change in use of out-of-class time;
- doing activities that were traditionally considered as ‘homework’ in class;
- doing activities that were traditionally considered as in class work out of class;
- in-class activities that emphasise active learning, and problem-solving;
- pre-class and post-class activities;
- use of technology, especially video;

For this article, I will use the term ‘flipped classroom’ as defined by the Flipped Learning Network (FLN) to refer to the mode of teaching and learning ‘in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space, and the resulting group space is transformed into a dynamic interactive environment where the educator guides students as they apply concepts and engage creatively in the subject matter’ (FLN 2014 para. 1). The FLN propose the ‘Four Pillars of Flip’ that recognise the significant features that are essential for learning to occur in a flipped classroom: (1) flexible environment, (2) a shift in the learning culture, (3) intentional content, and (4) professional educators (FLN 2014). This framework was considered to account for diverse learning modes, and its implementation necessitates the arrangement of flexible learning environments that may include, for example, the rearrangement of learning spaces and the use of digital technologies.

The Four Pillars of Flip framework is appropriate for gaining a better understanding of how the flipped classroom approach is implemented in practice. This framework is appropriate when analysing data about the teacher’s role in organising the teaching materials in the flipped classroom. Abeysekera and Dawson (2015) proposed a theoretical model for the flipped classroom (see Fig. 1) that identifies the capacity of the flipped classroom to help students have a sense of competence, relatedness, and autonomy that will lead students to increased extrinsic and intrinsic motivation.

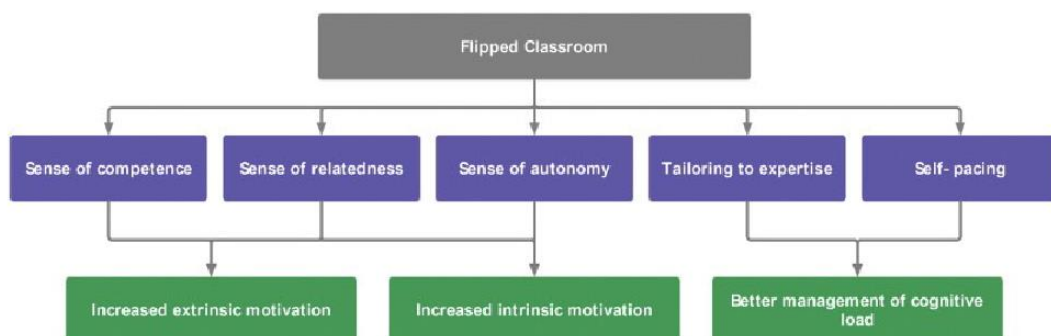


Figure 1 Theoretical model for the flipped classroom

Moreover, a flipped classroom approach is characterised by tailoring teaching material and activities to students’ different expertise that allows students’ self-pacing of pre-recorded lectures that may reduce cognitive load and help learning in a flipped classroom.

The theoretical model for the flipped classroom was considered appropriate for interpreting data pertaining students' engagement and motivation while it is required measurement of the cognitive load and motivation that are useful mechanisms for learning. The flipped classroom approaches are being adopted with enthusiasm despite the lack of specific evidence about their efficacy. However, substantial research questions remained unanswered. This article is particularly interested in university lecturer's implementation of the flipped approach in her practices. A small-scale localised intervention, including an experimental study, was conducted to understand the significant features of the lecturer's role against the essential criteria for learning to occur in a flipped classroom approach.

Methodology

An exploratory case study methodology was chosen as it involves a detailed study of a group of pre-service teachers' experiences. The data collected for the case study was both qualitative and quantitative. Analysis methods were employed (Creswell 2003) to provide richness and depth to the empirical investigation of a single university unit within its real context using multiple sources of evidence such as the lecturer, the entire cohort of preservice teachers who enroll in and attend the unit of study, and the teaching and learning resources that were used by the pre-service teachers.

The choice of the lecturer and her class was purposive in that the lecturer had indicated a strong desire to improve aspects of her online teaching related to student engagement, motivation, and self-pacing. The lecturer used a flipped classroom approach, and the appropriate technological infrastructure and digital technologies was in place to provide students with access to all teaching resources.

The study was conducted with the lecturer and her 185 pre-service teachers who attended an online unit that was required for a bachelor in Primary education or master in teaching Primary Education. The unit covered the content and pedagogy appropriate to teaching primary school students at stage 3 (year 5 or Year 6) in the strands of Data, Chance, Patterns and Algebra, and Number (numeracy). Students were asked to demonstrate their personal content knowledge in these strands, discuss associated teaching strategies, and create developmental learning sequences. The prescribed textbook, (Siemon, D., Beswick, K., Brady, K., Clark, J. and Faragher, R., 2015) was used to guide decisions about the sequence of mathematics topics to be taught. The textbook was used in combination with the Australian Curriculum (ACARA, 2016).

The lecturer prepared lectures recorded by Echo360, and offered two interactive online tutorials that were offered in real time by Adobe Connect. Each online tutorial was scheduled for two hours and students were able to ask questions and complete the tutorial activities with the help of the lecturer. Students who were not able to attend the online tutorials had access to the recording of the tutorials (in asynchronous mode). Additionally, demonstrations, electronic resources and relevant readings were available for students' use on the Moodle learning platform, which served as an online learning space where students interacted with each other, posted questions and engaged with collaborative activities (i.e. students were constantly experiencing feedback).

All students had access to the internet, and the online materials were also available for downloading in their own computers. The students were encouraged to assess the recordings of the online lectures, online tutorials, resources and assessment tasks for each topic.

Participants included one lecturer (Dr. April, pseudonym) and 185 students who attended the online unit. 142 students completed the online survey and 5 (3 females and 2 males) volunteered to participate in the semi-structured interviews. Dr. April, the lecturer had been teaching tertiary education for 7 years and was qualified to teach mathematics education to pre-service teachers and in-service teachers within primary and secondary and post-graduate programs. She had experience in using features of flipped classrooms for 7 years.

Data collection instruments consisted of an online survey that contained 18 questions about the use of the lecturer-prepared online resources. Responses were recorded against a five-point Likert scale. Semi-structured interviews were developed by the researcher to allow the lecturer to probe the pre-service teachers' experiences of the flipped classroom approach in this discipline. Pre-service teachers' online activities, postings, pre-service teachers' participation per day and the semi-structured interview of the lecturer were used to triangulate the data collected from pre-service teachers. All interviews were audio-taped and transcribed. Pre-service teachers' responses were coded and ascribed to five thematic categories as identified by Abeysekera and Dawson (2015). Lecturer's responses were also analysed and coded in four thematic categories based on the four Pillars of FLIP framework.

Results

In this section we present an analysis of the data collected from interviews with the lecturer, which was analysed using the Four Pillars of FLIP as a framework to recognise the significant features of the lecturer's role against the essential criteria for learning to occur in a flipped classroom: (1) flexible environment, (2) a shift in the learning culture, (3) intentional content and (4) professional educators. The data is supplemented with survey and interview data from the pre-service teachers.

Flexible environment:

When the lecturer was asked about the flipped teaching environment in an interview, she commented:

Dr April: Students are expected to view the online lectures and the online resources (videos) any time that is best for them because they are mature students who study this online unit and they prefer working during night hours.

Dr April: I am trying to extend classroom into their home where students cover the weekly teaching content and work the routine tasks and examples at home prior to the weekly lecture.

Students reported to making very good use of the online resources prepared by the lecturer and the recordings of the online tutorials at home, indicating that both were helpful for their mathematical learning and the completion of their assessment. As stated by two students, George and Sarah:

George: I do not worry if I missed the real-time online tutorial due to my family commitments. I have the capacity to access the recordings of the online tutorials and lectures at any time I wish.

Sarah: It is fantastic because I can watch the entire online tutorial or lecture without pausing it. But sometimes, I will watch it and pause it to write my notes about it. If I would like to repeat a part of it, I will simply go back to the part I need to listen again. I refer to certain parts many times because they are very essential for the online course.

A shift in the learning culture

Dr April relegated the more procedural demonstrations of solving a mathematical problem or constructing a mathematical application using mathematical software for the pre-service teachers to watch outside of the online tutorial time. As she commented:

Dr April: It is fantastic because it frees up teaching time instead of spending half of the time of the tutorial to show students the procedure of solving a mathematical problem with or without the use of mathematical software. I am trying to maximise the tutorial time by covering the key aspects of the weekly content taught and the teaching techniques of teaching school students a target content.

The students reported that they make good use of Dr April's video based procedural presentations and demonstrations. For example, John and Jill (pseudonyms) said during an interview:

John: I first listened to the online tutorials. I do find the online tutorials very helpful because the lecturer explains the mathematical content by applying the mathematical concepts in real life situations and solving mathematical problems. If you first watch the online tutorial very carefully it explains the mathematical content, application of mathematical content, primary students' difficulties in understanding specific concepts and pedagogical approaches and appropriate to teaching these primary students.

Jill: Dr April's video based resources are very helpful to understand the content at home on my own without attending traditional classrooms.

George: The online tutorials allow me to interact in real time with a group of other students and the lecturer, so I do not feel lonely during my studies. I post my questions on Moodle platform when I am stuck or unsure of the correct process.

Intentional content

Dr. April selected the content, decided on ways to present this content, and what resources (e.g., interactive whiteboard activities, or interactive games) would be appropriate for the online tutorial. As Dr April said:

Dr April: In the video-based resources that students are expected to view before the tutorial, I demonstrate how to use technology when they teach, for example I demonstrate how they insert data in a table using Tinkerplots and create various graphical representations of data and analyse data. Or I explain the use of interactive board activities or educational games that would help pre-service teachers to teach students how to compare fractions using computer based interactive tasks.

Dr April's approach included the use of technology to transform the teaching content from the textbook into video format that allowed her to unpack mathematics in more depth during the online tutorials and lectures. She also prepared materials and videos that related mathematics more directly to cross curriculum priorities such as Aboriginal and Torres Strait Islander history and cultures, Asia and Australia's engagement with Asia, and sustainability.

Moreover, pre-service teachers commented that the digital technologies employed by their lecturer to teach mathematics had provoked rich discussions amongst the pre-service teachers, allowing them to access the step-by-step instruction as the lecturer intended.

Professional educators

As Sarah noted, when asked if there was anything about the online teaching of Dr April that helped her particularly to develop her mathematical learning:

Sarah: The technology she uses helped me to visualise abstract mathematical concepts ... the presentations help me to visualise the graphical presentations as she manipulates the graphical representations to help me to observe the impact of dragging the graph to the algebraic equation of the function. She is explaining very well and clearly all the step-by-step procedures and their dynamic behaviours. I am really amazed by the animations that she provided to show the dynamic behaviour of mathematical concepts.

John also pointed out:

John: I feel that Dr April's videos are giving mathematics life. They explain mathematics better than the textbook does. I really prefer the recordings of the online tutorials because Dr April explains in detail what she is doing step-by-step using a very simple language.

George and Sarah also mentioned that:

George: the presentations are very professional and the quality of the sound is perfect. The recordings of the online lectures and online tutorials were easy to follow and although mathematics was not my strongest subject of study, I enjoyed my study. I found those recordings very engaging.

Sarah: I had all the online resources on my laptop and I study them while I am writing my assignment. I listen also to the online tutorials and lectures to write my assignment, but I do not use the prescribed textbook.

As indicated, the online resources were more appealing to the pre-service teachers and preferable to the prescribed textbook. The preparation of the online materials used for the pre-service teachers to access on their own exemplifies the enactment of the first, second, and third pillars of the flip framework. There was a shift from a static to a dynamic representation of the content and an intentional selection of the aspects of direct instruction that could be assessed in students' individual spaces.

Summary of 142 pre-service teachers' responses to the Likert items

Pre-service teachers indicated that they found the online resources prepared by Dr April to be very helpful for their mathematical learning (Q1, 96%). They also indicated that the online resources prepared by the lecturer are easy to follow and flowed well (Q2, 97%) and they agreed that they are engaging and interesting (Q3, 100%). The resources prepared by their lecturer were favoured over other online resources (Q4, 89%). Responses to the survey also indicated that pre-service teachers did not use the internet resources to help them with their mathematics learning (Q5, 73%). Pre-service teachers indicated that they found the online lectures relevant and meaningful, and they assist them with their mathematics learning (Q6, 96%). They also indicated that the online lectures were easy to follow (Q7, 99%) and they were about the right length (Q8, 95%). Significantly, respondents also found that the online tutorials offered them a great opportunity to answer questions about the mathematical content (Q9, 95%), fitting nicely into their schedule (Q10, 87%), being interesting and engaging (Q11, 89%; Q12, 2% boring). Interestingly, responses indicated that they make use of the

'Online tutorials' to explore mathematics (Q14, 5%) and they rarely use the 'Online tutorials' as a last resort when they were stuck on problems (Q15, 12%). However, they seemed to believe that they did better on the assessment because they watched the online tutorials (Q16, 82%). Importantly, pre-service teachers also believed that the step-by-step 'Demonstration of Mathematics software' was simple to use and it was beneficial (Q17, 93%), with only 1% of the responses indicated that the 'Demonstration of Mathematics software' was lacking and it required more technical tools (Q18, 1%); a possible consequence of the selection of the intentional content that Dr April expected students to cover before attending the online lectures and tutorials.

Conclusion

Dr April's attempt to implement aspects of a flipped classroom approach to her online course was made possible within a highly structured teaching and learning content because of the robust technological infrastructure in the university. Nevertheless, the pre-service teachers' engagement with their study of the online course was a consequence of the online resources developed by the lecturer to support her students' online learning. It would appear that pre-service teachers appreciated the opportunity they were offered to progress through materials at their own pace exercising a degree of autonomy in developing their own mathematical competence.

The four Pillars Framework afforded insights into the specific features of Dr. April's implementation of the essential features of flipped learning. The analysis of the data showed that Dr. April has provided students with a *flexible environment* that provided students with a *sense of autonomy* and *self-pacing*. Reflection on lecture's practice indicates a *shift in the learning culture* by transferring direct instruction from the classroom environment to home. The flipped classroom approach was implemented without removing the synchronous interaction of pre-service teachers with other students and the lecturer. It is noteworthy to point out that the interactive online tutorials aided in preventing students from being alienated from other students, the lecturer and the teaching materials. The selection of the intentional content was challenging in order to *tailor* the content to different *students' expertise*. Pre-service teachers appeared to be motivated to access the online resources prepared by Dr. April stressing the importance of *relatedness* between students and materials prepared by the lecturer to foster a version of an online flipped classroom. There was evidence that pre-service teachers engaged in rich mathematical discussions about the content of the teaching materials, showing that a flipped classroom can increase motivation and interaction amongst students and learning of ideas aimed by the provided teaching materials. The fourth Pillar of the flipped learning, the *professional educator*, appeared to be the agent of the flipped classroom approach. A *professional educator* (as Dr. April demonstrated) could foster the implementation of the flipped classroom approach in teaching and learning practices without making radical change to their current pedagogical approaches— a finding consistent with research conducted by Muir and Geiger (2016) who found that a flipped classroom approach could be implemented without radically reforming a teaching practice. Future studies could examine the suitability of flipped mathematics classroom approaches in different teaching contexts, such as inquiry learning contexts, teaching school mathematics, and whether or not it would be effective in improving students' learning outcomes.

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