

On Flipping the Classroom in a Large First Year Calculus Courses

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Abstract

Over the course of two years, 2012-2014, we have implemented a “flipping” the classroom approach in three of our large enrollment first year calculus courses: differential and integral calculus for scientists and engineers. In this article we describe the details of our particular approach and share with the reader some experiences of both instructors and students.

1 Introduction

The flipped classroom (or inverted classroom) teaching model has received a lot of attention in recent years, primarily due to the available use of technology for recording and distributing video lectures. However, despite a great deal of media attention to the flipped classroom ([1], [7]) research regarding the specifics of this pedagogical approach is only beginning to be published ([3]).

What exactly is the “flipped classroom”? This is a very broad term that encompasses a lot of other teaching methods. At its very heart it describes an approach where in-class time is repurposed for inquiry, application, and assessment (Figure 1). Central to the idea are the two stages required to gain new knowledge; first the student must *gather* information, secondly they must *assimilate* this information. The information gathering stage is what is often focused on in the traditional lecture model [9]. In this model students meet in large lecture theatres, instructors present information and students dutifully record/consume this information. After the lecture students are left to make sense of this information on their own, connect these new ideas with prior knowledge, and apply this information to solve problems. The “flipped” model attempts to switch which of these two stages takes place in the classroom. The responsibility for the information gathering stage is given to the student to do outside of the classroom, and the assimilation stage is moved into the classroom where the instructor can guide students in what may be considered the more challenging of the two stages.

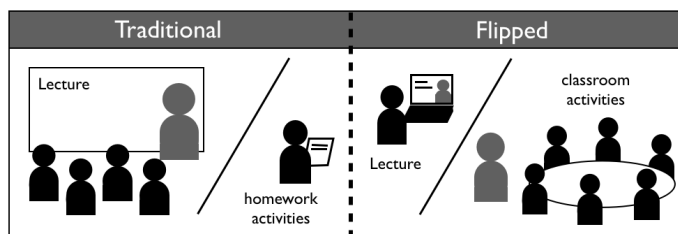


Figure 1: A basic representation of the “flipped classroom” as compared to the traditional class with formal in-class lectures.

Although flipped classroom pedagogy is not a recent invention [9] (pre-readings followed by classroom discussion provide one example of implementation), it has become increasingly popular over the past few years. A number of factors contribute to this change: the increased availability and versatility of media and communication technology allow instructors to produce recorded lectures and disseminate them online fairly easily and at a relatively low cost; the persistent emphasis on the importance of STEM subjects is propelling research and experimentation into new and innovative classroom practices; and the Khan Academy and MOOCs have directed tremendous attention to the use of instructional videos to support active and flexible learning inside and outside of the classroom.

Implementations of the flipped classroom are differentiated by how information is delivered outside the classroom, and how learning activities are designed and executed inside the classroom. Our approach and investigation are informed by research on STEM education using active learning, peer instruction and just-in-time teaching ([2], [4], [6], [8], [9], [11], [12]).

In what follows we will describe the particular implementation of the flipped classroom pedagogy that we used, provide a glimpse into the learning activities used in the classroom, and present some students feedback regarding their experiences.

2 Settings

We focussed our attention on differential and integral calculus for science and engineering students, which are the standard first-year large-enrollment calculus courses offered at most North American colleges and universities. Math150 is equivalent to Math151 except that Math150 is for students with no previous exposure to calculus and includes review material. Math151/152 meets for 50 minutes three times a week, whereas Math150 meets four times per week. We flipped roughly one class per week in each course. The following table summarizes the details of each course.

semester	course	title	enrolment	instructor	# flipped classes
Fall 2012	Math150	Calculus I: Differential Calculus	220	Jungic	8
Fall 2012	Math152	Calculus II: Integral Calculus	256	Mulholland	9
Fall 2013	Math151	Calculus I: Differential Calculus	342	Mulholland	8
Spring 2014	Math150	Calculus I: Differential Calculus	120	Mulholland	9

Each flipped class corresponded to a single topic. For example, the *chain rule* was one topic, *Newton's method* was another. The teaching of the topic was broken down into four phases, phases 1, 2 and 4 occur outside the classroom.

- Phase 1: **Information gathering** - students watch a pre-recorded video lecture, or read the textbook.
- Phase 2: **Preliminary assessment** - students do the online quiz (due the evening before the flipped class). The feedback the instructor receives is used to inform his or her focus on content in the classroom.
- Phase 3: **Assimilation of information** - in class, students work through problems individually and in groups (responses are collected using clickers, instructional methods such as peer instruction and just-in-time teaching are used)
- Phase 4: **Homework** - students continue to make sense of information by working through questions on the weekly homework assignment, which consists of both online (computer graded) and handwritten (TA graded) questions.

3 Pre-recorded Lectures

We use video lectures for delivering information outside the classroom, combined with skeleton lecture notes. Students watch the video lecture and take notes in the lecture note templates that are available as a downloadable pdf through the course management system. In this section we address two questions we are most frequently asked: (1) "How long does it take to make a video?" (2) "What equipment was used to make videos?"

On average one video lecture is about 30 minutes in duration, and it typically takes 3 to 4 hours to record, edit, and post the video online.

We have been experimenting with the use of videos in calculus for five years and do all the recording and editing ourselves. It has been a steep learning curve but one that we felt was well worth the time invested. The latest iteration of videos makes use of a green screen so we can insert the instructor into the writing area without a distracting background box. See Figure 2, or [10] for a link to the sample video.

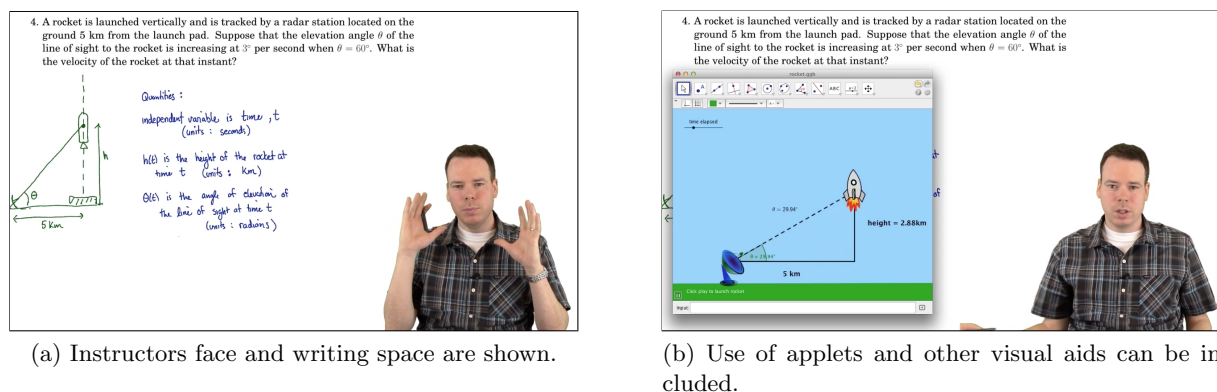


Figure 2: Screen shots of pre-recorded video lectures. Students are asked to watch the video lecture, taking their own notes on the provided skeleton notes available as a downloadable pdf, and read the corresponding section of the text, in preparation for classroom activities.

Guided by the golden rule that audio makes or breaks the video we record sound with a high quality digital audio recorder. We converted an office into a recording studio outfitted with green screen, lighting, interactive display, video and audio recorders.

Equipment used (in Fall 2013 - Spring 2014):

Video capture of instructor's face:

- Cannon Vixia HF R400
- Green Screen & EZ Softbox 5 Point Lighting Kit

Handwriting capture

- Wacom Interactive Display DTU-2231 (connected to a Mac)
- \LaTeX for producing pdf note templates
- Curio software (OS X) for handwriting on the pdf's
- ScreenFlow (OS X) for screen recording ¹

Audio

¹If you use Windows then OneNote and Camtasia could replace the last two items respectively

- Zoom H4N digital audio recorder
- Audio-Technica ATR-3350 lavalier microphone plugged into the Zoom

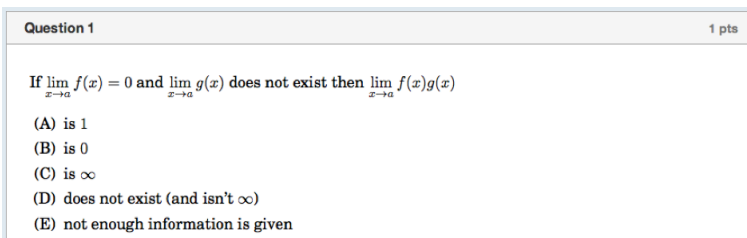
Putting all the video and audio components together and editing:

- Adobe Premier Pro

4 Pre-class Quiz

After the student has gathered the relevant information, either by watching the video lecture or reading the textbook, they are assigned an online quiz (administered in our learning management system Instructure Canvas). A sample question is shown in Figure 3a. A quiz will consist of about 5 to 8 questions and students are given two attempts. Full feedback is given after the submission of their first attempt, and the second attempt pulls a new set of randomized questions from a pool of similar questions. Students receive 2% of their final grade solely for participation in this quiz.

The instructor reviews the results of each question and use this feedback to determine what concepts to focus on in the classroom the next day. In Figure 3b we see that students are still having troubles with these concepts so this is worth discussing in the classroom.



(a) A sample pre-class quiz question.



(b) Student responses to question. Correct answer is E.

Figure 3: Pre-class quizzes are used to gain feedback to inform our teaching.

Question formats for the quiz range from multiple choice, true/false, free response, and formula response. Some of the questions we use in the quiz come from the excellent *Good Questions for Calculus* collection from Cornell University [5].

5 Inside the Classroom

This is where the magic happens. The room of 340 students (Figure 4) erupts into chaos when the instructor asks the students to persuade their neighbours that their answer is correct. Students are calculating, gesturing, arguing, helping each other, teaching each other, and most importantly learning from each other.

Using the feedback from the pre-class quiz the instructor comes to class prepared with a list of about fifteen questions centred around the concepts that students are still having problems understanding. The instructor does not expect to get through more than six questions, but *which* six we use is still, at this point, an open question. This is determined as the class progresses through the next fifty minutes.

The instructor displays a question on the screen and ask the students to work on the problem individually at first. Students are given three to five minutes to work on the question and then submit their response via their clicker. The results of this first polling session is shown to the

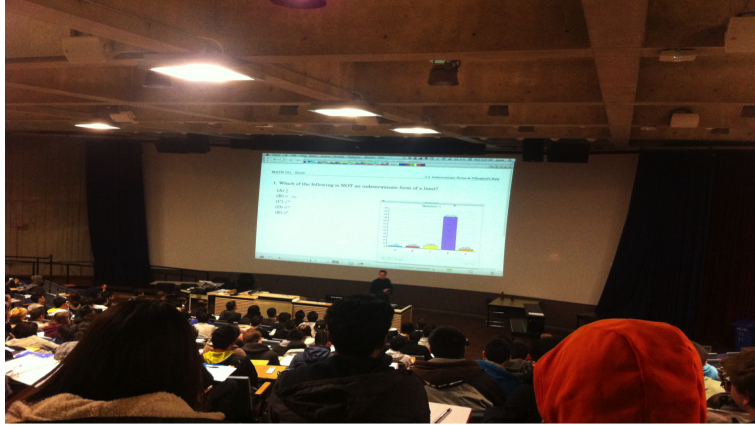
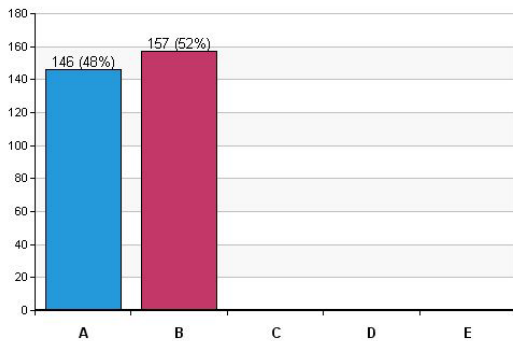
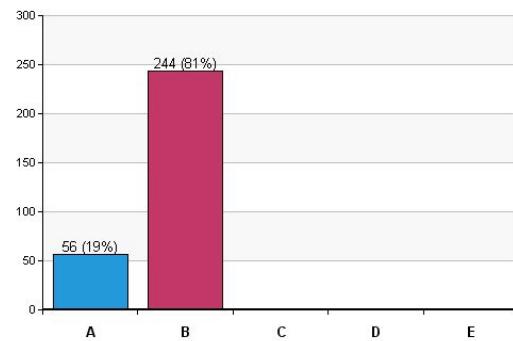


Figure 4: A view from the back row of Math151, Fall 2013. Enrolment 342 students.

students, but the correct answer is not revealed. See Figure 5 for a sample question and 5a for the results of the first round of polling. At this point, the instructor asks students to talk to their neighbours and attempt to convince each other of their choice of answer. The room breaks out into conversation, the instructor moves throughout the room talking with students. After another three minutes students submit their responses and results are shown. For an observer it is impressive to witness the convergence of the class to the correct answer with little or no input from the instructor. This is the heart of peer instruction. See Figure 5b. At this point about 20% of the class still has the incorrect answer, so this is a good time for the instructor to quickly work out the solution to the question, then reveal a follow-up question for students to try again.



(a) First round: students work on problem individually. Correct answer is B.



(b) Second round: students encouraged to discuss with their neighbours.

Figure 5: **True** or **False** If $f(x) = x^{1/3}$ then $f'(0)$ exists. (A) True (B) False

It doesn't always work out in this way, and the instructor needs to gauge if or when to provide instruction. For example, the instructor asked the following question to the Math150 class.

The derivative of $f(x) = x|x|$ at $x = 0$

- (A) is 0.
- (B) does not exist, because $|x|$ is not differentiable at $x = 0$.
- (C) does not exist, because f is defined piecewise.
- (D) does not exist, because the left and right hand limits do not agree.

First round polling results are shown in Figure 6a. Fearful that those students that selected D may persuade that rest of the class to move in that direction (we have experienced this before) the instructor decided to ask the simple, perhaps obvious, question: *The question is asking about the derivative, did you try to calculate the derivative using the definition?* At this point in the course, differentiation rules have not been covered so the definition of derivative is all the students have to work with. Students then discussed the question with their neighbours for about two minutes, and the results of the second poll are shown in Figure 6a. There is an absolute silence in the room waiting to hear confirmation that the majority is correct. The instructor has their complete attention, so the instructor quickly works through the details, arrives at the answer, and the class breaks out into a cheer. This activity made students *want* to know the answer.

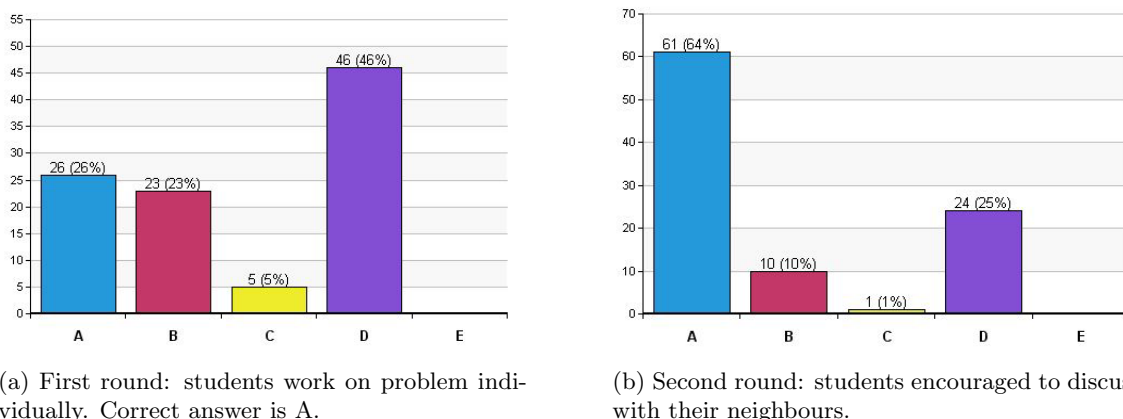


Figure 6: A question asking about the derivative of $f(x) = x|x|$ at $x = 0$.

6 Back at home

After the flipped class the students are to work through the assigned homework problems for the week. This is designed to reinforce the content of the video lecture and the classroom practice. Students are encouraged to read the textbook at this stage if they have not done so already. It is worth noting that students are actively participating in the online discussion forum within the course management system. Peer instruction has continued beyond the walls of the classroom. At the end of the week students write an in-class hand-written quiz which assesses their understanding of the assigned homework.

7 Student Experiences

For each course we surveyed students after the first midterm (week 5) and again at the end of the term (week 13) asking for their feedback on our implementation of the flipped classroom model. Below is a very brief summary.

Perceived benefits of the video lectures:

Respondents agree or strongly agree that the video lectures helped them better prepare for class, learn at their own pace, answer clickers questions in class, prepare for exams, and learn better in general.

Top features of the video lectures:

The three top features of video lectures, the respondents consistently cited the following: ability to access at anytime, ability to review the parts they didn't understand or missed in class, and ability to learn at one's own pace. Contrary to the common belief that it is unnecessary to show the speaker in the video (i.e. that a voice is enough), a significant number of respondents from both courses said they liked the fact that the same instructor (as in-class) was on screen talking to them in the videos. This seems to indicate a psychological benefit to the fostering a personal feeling of connection in the videos.

Areas of improvement of video lectures:

When asked what they would like to see improved in the video lectures, the most frequently mentioned feature request was the ability to comment and ask questions when watching the video.

Students perceptions of peer instruction:

To investigate students' perceptions of peer instruction, we asked respondents to rate the following statements on a scale from 1 (strongly disagree) to 5 (strongly agree).

- Working in pairs or small groups in class helps me to learn better.
- Discussing clicker questions with other students in the class helps me to better understand the subject matter.
- Hearing other students explain their understanding of a problem helps me to learn better.
- Having to explain my own understanding of a problem to other students helps me to learn better.

Respondents from both courses consistently gave high ratings to all four statements.

8 Conclusion

After using this implementation of the flipped classroom model we can emphatically say that this is our new norm. We feel more engaged with our large classes, and with the pre-class quiz and in-class clicker questions we have our finger on the pulse of the student and are able to address misconceptions immediately as they arise, not days or even weeks later after receiving results from major assessments. At our weekly debriefing meetings we mentioned on numerous occasions that during the flipped classes we felt like we were *really* teaching, and making a real difference. The classroom was an exciting place to be for the instructor and the students.

We should note that impact on learning achievement is inconclusive at the current stage; however, we remain cautiously optimistic about future results as we move into the next iteration of our study.

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