**On instructor experiences in three flipped large undergraduate calculus courses**

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*This is a study of instructors who undertake the flipped classroom pedagogy and how it impacts their instructional practice in terms of material preparation, classroom delivery and interactions with the students, time commitment and their changing role as teachers. Qualitative data were collected through weekly after-class debriefs with instructors, extensive classroom observations throughout the semester, and end-of-semester instructor interviews. These data were supplemented by quantitative data from surveys of students' perceptions of their flipped classroom experience. Our findings include: significant skills, planning and time investment are required of instructors to produce good quality video lectures that students would watch and perceive as beneficial for their learning; instructors' view of the importance of covering content is replaced by that of uncovering the content so that students are able to apply concepts in solving problems; preparing clicker questions that address conceptual understanding is critical in our model of flipped classroom; the changed role of the instructors in the flipped classroom is both challenging and invigorating.*

**Keywords**: flipped classroom; just-in-time teaching; calculus; math education; teacher experience

## Goals and Objectives

This investigation is a part of a larger effort aimed at a sustained transformation of how large introductory calculus courses are taught at university. This paper explores the experiences of two instructors who taught three first-year large undergraduate calculus courses using flipped classroom pedagogy between fall 2012 and fall 2013. The idea of the flipped (or inverted) classroom is to use technology to shift lectures outside the classroom, reserving class time for homework, practice with concepts and other learning activities (Strayer, 2007). Although flipped classroom pedagogy is not a recent innovation, it has become increasingly popular over the past few years as a blended learning approach, supported by consumer video technologies and motivated in part by efforts to improve STEM education (Berrett, 2012a; Davies, Dean & Ball, 2013).

Despite its popularity, research regarding the specifics of the flipped classroom is only beginning to be published (Davies, Dean, & Ball, 2013). Most of it focuses on showing that the method has worked from the perspectives of students and their learning (e.g., Crouch & Mazur, 2001; Lage, Platt, & Treglia, 2010, Davies, et al., 2013). To complement this body of research, our study investigates what it takes for instructors to undertake the innovation and how it impacts their instructional practice. We hope this will inspire sustained pedagogical advancement and inform others who wish to initiate similar practices.

## Theoretical Framework

One recent survey study of 722 faculty members in physics shows that one out of three of the faculty members who tried the active learning methods including flipped classroom strategies reverted back to traditional lecturing (Henderson, Dancy & Niewiadomska-Bugaj, 2012). Although a willingness to try different methods is widespread, they can be difficult to sustain (Berrett, 2012b). Reasons can be practical, psychological, and social. These include trying to cover the same amount of (often too much) content, giving in due to intense student complaint, underestimating the amount of instructional preparation required to make necessary changes to one's pedagogy, misjudging the additional and often unanticipated effort called for during implementation, or not sticking to the method long enough to see the benefit, etc. (Berrett, 2012b; Knight, 2004; Michaelsen, Knight, & Fink, 2004).

Bruff (2013) asserts that the central question at the heart of the flipped classroom idea is how instructors make the most of the relatively limited time they have with their students during class. Furthermore, class does not take place in isolated time and space; context matters (the course, the students, the instructor, and the material) (Bruff, 2013). The instructor is at the heart of all these matters. Drastic pedagogical innovations require that the instructor reconstruct the learning environment and his/her role in that new environment.

## Context

Between fall 2012 and fall 2013, two experienced senior mathematics instructors incorporated the flipped classroom pedagogy into three first-year large undergraduate calculus courses. The two instructors, Jason and Matt (pseudonyms), are both teaching award recipients. The three flipped courses were: Calculus I (C-I) and Calculus II (C-II) taught by Matt, and Calculus I with Review (C-I-R) by Jason, with class sizes of 346, 246, and 224 students respectively. C-I-R is designed for students with no previous calculus experience. C-I, covering exactly the same content as C-I-R, is for students who took calculus in high school. C-II takes in the students who succeeded C-I-R or C-I. The experiment was carried out in two rounds. C-I-R and C-II was conducted in the first round of the flipped classroom implementation in fall 2012, while C-I was conducted in the second round in fall 2013.

Applications of the flipped classroom idea are differentiated by how they deliver lectures outside the classroom and by how learning activities are designed and executed inside the classroom. We designed our model to combine the use of instructor-made video lectures, i>Clickers (a classroom response system), peer instruction (Crouch & Mazur, 2001; Knight, 2004; Mazur, 1997 & 2009), and just-in-time teaching (Simkins & Maier, 2010; Smith, Wood, Krauter & Knight, 2011).

Each week, the instructor: 1) prepared regular 50-minute lecture classes for Friday and Monday; 2) produced the lecture videos (of the 25 40-minute videos, eight were made before the courses started); 3 reviewed students' post-video-watching quiz results and prepared 12 to 24 clicker questions with a range of difficult levels to specifically address problem areas; 4) conducted peer instruction and just-in-time teaching in the flipped class on Wednesday, followed by after-class office hours; 5) administered an in-class quiz (consisting of two items randomly selected from the homework assignment) and gave a lecture on Friday; and 6) monitored online discussion about video lectures and course materials, and answered student emails.

## Methodology

Our overarching research methodology is design-based research (Bell, 2004), whose goal is "to describe how interventions worked and [is] less about documenting that they worked" (O'Donnell, 2004, p. 255). We aim to iteratively improve a flipped classroom model that works for our instructors, our students and our courses. For this particular study of instructors' experience we used qualitative methods, including 30-60 minutes weekly after-class debriefs with the instructors, extensive classroom observations throughout the semester of both the flipped classes and selected non-flipped classes, and two-hour end-of-semester instructor interviews. These data are supplemented by quantitative and quantitative data collected from surveys of students' perceptions of their flipped classroom experience (n=430, response rate 53%). The data from students' perspectives provided triangulation and explanation for some of the instructors' observations and reflections.

## Results and discussion

What follows is a discussion of the two instructors' experience in preparations of video lectures and clicker questions, interaction with the students, just-in-time teaching, content coverage, time commitment and overall evaluation of their experience.

*Preparing video lectures*: During our two-round experiment, the instructors produced two generations of video lectures. Without any training or support, the instructors produced the videos used in the first-round of implementation of C-I-R and C-II. On average, each instructor spent six hours to produce a 40-minute lecture. After the initial experimentation on his own, Matt sought out the support services provided by the university's teaching and learning center. After 60 hours training and practice (including 48 hours of workshops, four hours of one-on-one consultation, and 8 hours of self practice), Matt was able to produce a same-length video with much improved audio and video quality in four hours.

Despite the significant amount of time required to make the instructional videos, the two instructors felt their investment was well worth the effort. They were energized by the level of usage and positive responses from the students. Our student experience questionnaire results show that students watched the videos regularly before coming to the flipped classes. Many of them discussed the video contents with their peers and some of them revisited the videos after class (more so during exam period). Overall, students from all three courses

felt that the video lectures allowed them to learn anywhere at anytime and helped them better prepare for class, learn at their own pace, answer clickers questions in class, and learn better in general.

*Preparing clicker questions*: When teaching the courses in traditional lecture mode, the instructors typically spent half an hour to go over the 50-minute lecture materials before class. The exercise became repetitious and mechanical after teaching the same course many times. "I can't remember how many hours I spent at my desk going over the lecture notes when I could be talking to students in tutorials. Now teaching becomes fun again!" (Matt). Instead of reviewing their own lecture notes, the instructors reviewed the post video-watching quiz results and identified areas of weakness and strength in students' understanding. "You never know what the quiz results will tell you." (Matt). There was often an element of surprise that intrigues the instructors and this made teaching refreshing and engaging. They prepared according to what student needed to practice and master the next day. Assembling, revising and creating new clicker questions that target the most challenging concepts the students face and address a range of individual learning needs becomes one of the most important instructional tasks. "The clicker questions are the key." (Matt). Often during our after-class debriefs the two instructors exchanged reflections and discussed extensively how students did on particular questions in class. These debriefs helped them improve their clicker questions and better prepare for their next flipped class.

*Just-in-time teaching and instructor-student interaction*: In class, instead of lecturing for the whole 50 minutes, Matt typically spent less then half of the time speaking to the whole class. Jason spoke between 30 to 35 minutes. When they were not lecturing, they were walking the aisles and in between the rows monitoring class activity; they stopped now and then to check on how students were doing; they crouched down to answer questions or give a hint. "I had good interactions with students I wouldn't have had otherwise." (Jason). "In the past I typically knew about 10 students. Now I know 40." (Matt). Just-in-time teaching shifts role of the instructor from a "sage of the stage" to a sage on side and a guide on the stage. Matt enthusiastically reported, "I enter the classroom feeling like a kid on the morning of the Christmas Day and wondering 'What are you [the students] going to bring me this time?'" In class, when polling was about to stop as the instructor counted down the seconds, one could feel the anticipation in the air. Often as soon as the result was shown, one heard the exclamation from the class. Sometimes it was a cry of surprise because of the wide distribution of answers; sometimes it was shout of joy because they finally mastered a problem as a class. "I just love it," said Matt.

Jason, who had a real sense of humor, would sometimes give an unexpected twist to his class. Instead of using a ready-made clicker question, he would create a question on the spot based on how students grasped a concept and invite his class to provide the options. When the class failed to provide more than two options, he would add "I don't know" and "I don't care" as two more options. The class laughed. When these options got chosen as shown on the polling results, students laughed again. For Jason, this was not simply a laughing matter, they equally provided instructor valid feedback of where students were at. "We had fun and we learned together. I would not be able to interact with my students without the technology [clickers]," said Jason.

From classroom observations, we consistently noted that instructors lectured when the class as a whole struggled with a problem. Instead of talking to the students, the instructors talked *with* the students. They referred to the conversations they heard and the discussions they participated in when walking around the class. They engaged students through back-and-forth questions and answers. The lectures became interactive. These observations agreed with the positive views of the students on their interaction with the instructors as reflected in student questionnaire results.

Outside of face-to-face classes, Matt encouraged his students to ask questions about the video lectures and course content in general using online forums. He now spent much less time answering individual questions via email and much more time in the forums. "I like this way better; students learn more from each other and it is saves time for me [from answering the same questions multiple times]." (Matt)

*Content coverage*: The instructors hypothesized that since the part of the course contents would be covered by the video lectures, it should free up more classroom time to deal with concepts that needed to be

reinforced. Indeed, Matt reported that for the first time in his teaching of C-I and C-II he was able to stay on schedule. Jason, on the other hand, did not manage to make it happen, "I was not very disciplined. I would stop and slow down because I feel my students need the baby steps." Our flipped classroom observations were that students in C-I-R seems to be more hesitated to work with the clicker problems than those in Matt's C-I and C-II classes. Both Matt and Jason agreed that students in Jason's class (first semester at the university with no previous calculus experience) are less prepared than those in C-I (also first semester at the university but who had previous taken calculus) and less mature than those in C-II (second year at the university). They needed more hand-holding. However, having seen Matt's success with students in C-I, Jason began to challenge his assumptions, "Maybe I am wrong. Maybe I can skip the baby steps." Jason plans to conduct his second round of flipped classes with adjusted expectations of his students and of himself. More significantly, having had the flipped classroom experience, both instructors realize that less is more. They have now decided to cut the lecture content by ten percent so that more time is freed up for both the instructors and the students to deal with the content more in depth. After all it is not about covering content; it is about how to uncover the content so that students understand and be able to apply what they have learned in solving problems.

*Time investment*: The initial time investment to prepare the video lectures is significant as reported earlier. In addition, our instructors spend on average 3.5 hours to prepare their clicker questions for each of the 25 flipped classes. This includes creating new questions and selecting the most relevant questions from the existing question pool. This compares to the 30 minutes needed to prepare for a traditional lecture class.

The investment in preparing classroom learning activities that address deep learning (e.g., conceptual understanding, problem solving or knowledge integration, whether in the form of clicker questions or other forms of active learning, such as problem- or case-based learning), is critically important and in some way more challenging than producing the video lectures. It requires the instructors to reconsider the usage of classroom time and imagine new ways to push learning beyond memorization and "plug and chug" (Mazur, 2009). It requires the instructors to switch from the "chalk and talk" mode (Knight, 2004) to a state of keen awareness of where the students are at and what they need next to advance their learning.

Despite the significant up-front time investment required to prepare the video lectures and learning activities, our instructors anticipate that they will be able to break even in the third-round implementation of the flipped classes, at which point they will be able to reuse the ready-prepared materials and tweak the clicker questions as needed.

*Overall reaction of the instructors*: Despite the time and effort required to carry the experiment, the two instructors are inspired by what they see in the classroom and the impact on their students' learning. They are invigorated by the experience. "There is no way back. We are committed to moving forward with it." (Jason and Matt). Having completed his second flipped course, Matt believes it is feasible and desirable to flip two classes each week instead of one when he teaches these courses next time.

**Conclusions and Significance of the Study**

To produce instructor-made video lectures requires time and skills. Universities should be prepared to provide not only technical training and support but also resources (including time) for faculty to redesign their courses and develop new curricula. Peer instruction and just-in-time teaching transform the role of instructors, demanding them to be thoroughly engaged with the students intellectually and psychologically throughout the class. This is hard work, but for some instructors, this is why they like it. We are only at the beginning of our flipped classroom experiment. We will continue documenting the experience and reflections of our instructors as we improve our implementation. We hope it will inform the teaching practice of others beyond our institution.

**References**

Bell, P. (2004). On the Theoretical Breadth of Design-Based Research in Education. Educational Psychologist, 39(4), 243-253.

Berrett, D. (2012, Feb 19). How 'flipping' the classroom can improve the traditional lecture. *The Chronicle of*

*Higher Education, 58* (25). Retrieved from http://chronicle.com/article/How-Flipping-the-Classroom/130857/

Berrett, D. (2012, Aug 31). Physicists eagerly try new teaching methods but often drop them, study finds. *The Chronicle of Higher Education.* Retrieved from http://chronicle.com.proxy.lib.sfu.ca/article/Physicists-Who-Flip-Their/134100/

Bruff, D. (2013, October 25). *Class time reconsidered: Making the most of 150 minutes a week*. Retrieved from http://derekbruff.org/?p=2742&utm_source=dlvr.it&utm_medium=twitter

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, 69(9), 970–977.

Davies, R. S., Dean, D. L., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Education Technology Research Development, 61*, 563-580.

Henderson, C., Dancy, M., & Niewiadomska-Bugaj, M. (2012). Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process? *Physical Review Special Topics - Physics Education Research, 8*(020104), 1-15.

Knight, R. D. (2004). *Five easy lessons: Strategies for successful physics teaching*. San Francisco: Addison Wesley.

Mazur, E. (1997). Peer Instruction: A User's Manual. Englewood Cliffs NJ: Prentice Hall.

Mazur, E. (2009). Farewell, lecture? *Science*, 323.

Michaelsen, L. K., Knight, A. B., & Fink, L. D. (2004) *Team-Based Learning: A Transformative Use of Small Groups in College Teaching*. Sterling, Va.: Stylus.

O'Donnell, Angela M. (2004). A Commentary on design research. *Educational Psychologist*, *39*(4), 255-260.

Simkins, S, & Maier, M. (2010). *Just-in-time teaching: Across the disciplines, across the academy*. Sterling, Va: Stylus.

Smith, M. K., Wood, W. B., Krauter, K., & Knight, J. K. (2011). Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *Life Sciences Education*, 10, 55–63.

Strayer, J. F. (2007). *The effects of the classroom flip on the learning environment: A comparison of learning activity in a traditional classroom and a flip classroom that used an intelligent tutoring system*. Unpublished dissertation, Ohio State University. Retrived from https://etd.ohiolink.edu/ap/0?0:APPLICATION_PROCESS%3DDOWNLOAD_ETD_SUB_DOC_ACCNUM:::F1501_ID:osu1189523914%2Cattachment