COMPARING A "FLIPPED" INSTRUCTIONAL MODEL IN AN UNDERGRADUATE CALCULUS III COURSE

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In this small comparative study, we explore the impact of "flipping" the instructional delivery of content in an undergraduate Calculus III course. Two instructors collaborated to determine daily content and lecture notes; one instructor altered the instructional delivery of the content (not the content itself), utilizing videos to communicate procedural course content to students out-of-class, with time in-class spent on conceptual activities and homework problems. Student performance on tests for both classes will be compared to determine any significant differences in achievement related to "flipping" the instructional delivery.

Key words: Flipped Classroom, Technology, Calculus III, Comparative Study

The educational landscape has been transformed in the past 25 years due to the accessibility and integration of technology in the classroom. One of the latest technological trends attempts to completely re-conceptualize the in-class and out-of-class experience: "flipping" the classroom. The premise for this instructional model is that student and teacher interactions during class time can be maximized by offloading course content onto videos or screencasts to be watched from home (Bergman & Sams, 2008). In this study, we explore the impact on student performance of "flipping" an undergraduate Calculus III course.

Literature

At the turn of the 21st century, educators began discussing the potential benefits of "inverting" the classroom model. Lage, Platt, and Treglia (2000) described the inverted classroom model as "events that typically take place *inside* the classroom now take place *outside* the classroom and vice versa" (p. 32); they presented anecdotal evidence through student and faculty perceptions of an undergraduate economics course to claim the model had potential to help create an inclusive learning environment for diverse students. In the past 10 years, increased accessibility to free video servers (e.g., YouTube), podcasts (e.g., iTunes U), and tablets with screencasting software have made this approach less cost-prohibitive and more feasible on a large scale (e.g., Khan Academy).

Two high school science teachers, Bergman and Sams (2008), popularized an analogous approach that has come to be known as the "flipped" classroom. In the past few years, technology conferences have included panels and had numerous sessions about the "flipped" model (e.g, ISTE Conference); there is also an annual conference (The Flipped Class Conference), an online professional learning community (Flipped Learning Network), and large funding for "flipped" initiatives in education (e.g., Gates Foundation funding the Khan Academy). However, while demand and interest are high and the rationale for the approach is compelling, the majority of research is either anecdotal or contains minimally convincing, non-comparative data collected within a single course (Bergman & Sams, 2008; Gannod, Burge, & Helmick, 2008). Perhaps the most rigorous study, which demonstrated statistically significant gains in a physics class from a comparative study (Deslauriers, Schelew, & Wieman, 2011), is only partially related to the "flipped" model. While there is optimism about its potential, some benefits of "flipped" instruction may not translate to mass implementation (Hertz, 2012). There is little information about how the "flipped" model impacts learning in various subject areas or age groups. We aim to add research to the existing literature about the "flipped" classroom approach that is: 1) specific to undergraduate mathematics instruction; and 2) has a comparative research design, to explore the causal impact of utilizing different instructional delivery models for identical course content.

Methodology

Two mathematics professors and a mathematics educator at a mid-size private university collaborated to study the impact of "flipping" an undergraduate Calculus III course. Two sections of Calculus III (each professor taught one) were both taught three days a week (50-minute class periods) during Fall 2012. The research questions addressed were:

Does "flipping" the instructional delivery in an undergraduate Calculus III course:

1. Impact students' overall performance, or their performance on procedural or conceptual mathematics problems?
2. Impact students' opinions and perceptions about the course regarding in-class and out-of-class interactions with the content and the professor?

For this research, problems on homework assignments and exams were categorized as primarily *procedural* or *conceptual*. The purpose in doing so was to add an additional layer of analysis into the study, aiming to report about whether the "flipped" instructional model had more impact on students' performance in either problem type. Adapted from the National Research Council (2001), we defined: *procedural* questions as those that primarily require carrying out a standard mathematical procedure or algorithm (e.g., calculate the partial derivative of a function); and *conceptual* problems as ones that primarily require explanation/generalization of mathematical concepts or application of procedures in non-standard settings (e.g., interpret the partial derivative of T=f(x, y, z) with respect to z).

To answer the first research question, significant efforts were made to make the content in two Calculus III courses as identical as possible in order to isolate the impact of instructional delivery. In addition, the labor of "flipping" the classroom was made into as simple and manageable of a process as possible. Data collected includes: student demographic information, attendance, homework completion, student exam scores, with sub-scores for procedural and conceptual problems, field notes from both classes, and a student perception survey. For this study, we characterize each model of instruction by the following:

Traditional instructional model: In-class, the professor primarily lectures by writing notes and examples on the board. Students mainly take notes, with minimal student-to-instructor dialogue and no student-to-student interaction. Out-of-class, homework problems are assigned for students to complete on their own.

"Flipped" instructional model: Out-of-class, students watch short videos (~20 minutes) prior to the class of a lecture prepared by the professor on primarily procedural course content. In addition, students complete one or two procedural homework problems based on the video. In-class, the professor facilitates whole-class and small-group discussions based on more conceptual course content, using additional problems from the lecture notes or homework problems. Part of the class period will be spent having students work on homework problems, turned into activities for learning more conceptual content.

During the Fall 2012 semester, two mathematics professors collaborated on lecture notes, homework assignments, and assessments for the course. The course was split into three units, with an exam at the end of each unit. For the first one-third of the course, both professors followed the same lecture notes and taught according to a traditional model of instruction. The purpose was to substantiate that students would perform similarly when the professors taught similarly. For the second two-thirds of the course, one professor continued to teach in a traditional manner whereas the other switched to a "flipped" instructional model. The mathematics education researcher helped establish a system to "flip" the instruction, from selecting video content to altering homework problems for meaningful in-class discussion.

To guarantee that students in both sections received nearly identical content under the two instructional models, the following precautions were taken: 1) *Both professors followed the lecture notes agreed upon for each class.* Professor A (traditional) gave a lecture in-class. Professor B ("flipped") selected the lecture notes that were primarily procedural and created a video for students to watch out-of-class; the remainder of the lecture notes was turned into discussion-based activities for in-class. 2) *Both professors assigned and collected the same homework problems.* Students of Professor A turned them in the following class period. Students of Professor B turned in one or two of the procedural problems after watching the video, and had the opportunity to work on and complete the remainder of the homework problems in-class, turning them in the following class period. This helped provide similar out-of-class time demands for both sections. 3) *Both professors gave identical exams*. The professors collaborated to write and select the exam questions for each unit. And 4) *Both professors graded exams.* To make sure there was no bias in grading, the professors split the grading so that each professor graded the same exam questions for both sections.

To answer the second research question, additional data will be gathered from a student survey at the end of the course and a group interview with a representative sample of students from each course. The researchers will write the survey instrument and interview protocol, taking into account instruments used in other research studies on the "flipped" model; both the quantitative and qualitative data should help answer the second research question.

Preliminary Findings

Nearly all students in both classes agreed to participate in the research study: 41 out of 45 in the traditional section, and 39 out of 44 in the "flipped" section. Based on an analysis of participating students' demographic information, there are no statistically significant differences ($p<.05$) in the student makeup of each course regarding: gender, age, ethnicity, major, class (e.g., freshman, sophomore), Calculus II grades, or SAT Math scores.

During the first one-third of the course, the mathematics educator researcher took field notes during two different class periods, which helped characterize the instruction for this period. While both professors had slightly different ways of explaining ideas and interacting with students, they covered the same content and their instruction was similar. Based on field notes and students' performance on the first unit exam, there was no statistically significant difference between the two sections in the distribution of scores ($p=.342$), indicating that student performance was similar when both professors used a traditional instructional model.

We are still collecting data from the rest of the semester (complete by December 2012). While we currently do not have data on the impact of the "flipped" approach, we have evidence that the participating students and professors are similar, which provides a good foundation for the comparative analysis. Once data has been gathered, statistical analysis for comparing the populations will be coupled with visual trends, as the size of the study may limit statistical conclusions. Drawing decisive conclusions about the effectiveness of different instructional models by comparing only two undergraduate classrooms is inadequate; however, the results from this study will add to the growing body of literature on the "flipped" model. In particular, the comparative design and efforts to make content as identical as possible to isolate the instructional delivery should give meaningful conclusions.

During the presentation, we will: detail our process for transforming lecture notes and the homework assignment into a "flipped" model with identical content; present data about the impact on student performance of the "flipped" instructional model; and discuss results regarding students' perceptions about the two courses. The questions we will discuss during the presentation include: What limitations do you see in our process of removing variables to isolate the content delivery, as characterized by the two instructional approaches? How manageable was the process for "flipping" lecture notes and homework assignments?

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