Teaching Engineering Computation Using a Flipped Classroom Model

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Introduction

Today the traditional lecture-based teaching is still widely used in STEM higher education. The lecture-based teaching is a very efficient way of delivering information, but it has been noted that use of the lecture as the only mode of instruction may not be the most effective way for students to learn. The shortcomings of traditional lecturing-based teaching include small amount of cooperation and interaction between the teacher and students, emphasizing the "learning-by-listening" learning style only, and having difficulty to keep the students' attention (student attention wanes quickly after fifteen to twenty-five minutes).[1] In STEM curriculum, a strong emphasis on engaging active learning and cooperative learning can meet the educational needs for twenty-first century students. One of the challenges to educators is how to integrate active learning practices while still delivering large amounts of information in a limited class contact time.

The flipped classroom approach provides a potential solution to the challenge. In a flipped classroom, instructors create recorded videos or voice-over PowerPoint slides that allow students watch outside of the classroom on their own time prior coming to the class. The class time can be used to help students practice and apply the knowledge from the lecture videos in an environment where students can receive immediate feedback. Many higher education institutions have included flipped classroom technique in some of their courses. Redekopp and Ragusa[2] flipped a computer organization and architecture course and found that the flipped approach increased students problem solving and modeling skills in computer engineering. Swartz et al.[3] implemented the flipped classroom strategy in three distinct engineering courses and one of their findings was that students were better prepared for class. Bland[4] reported that the flipped classroom approach actually allowed more content to be covered in a course. He et al.[5] noted that using lecture videos allowed students to pause, take notes, look for references and rewind the lecture to better understand the material and move at a personal pace. Bergmann and Sams[6] found that the flipped classroom model helped students develop an awareness about the importance of self-learning and take responsibility for their own learning.

The purposes of the study are to determine if the flipped classroom model is acceptable to students in community college settings and to discover the student attitudes toward the new

teaching pedagogy. Assessment data are collected to examine students' use of online video lectures. Student performances on common exams are analyzed and compared to results from previous offerings that were conducted in traditional lecture-based settings.

Methods

The course examined in the study is a sophomore-level engineering computation course, CS221-First Course in Computer Science for Engineers. This course provides students with the necessary knowledge and skills to use modern computational techniques and tools to solve engineering problems. It also serves as an introduction to the fundamentals of numerical analysis as applied to engineering problems and to structured programming. The typical topics covered in Excel include introduction to Excel, graphics with Excel, Excel functions, matrix operations, linear regression, solving set of equation, finding the roots, data analysis and statistics functions, differentiation and integration. The topics covered in MATLAB include MATLAB fundamentals, script and function files, basic data plotting, input and output, looping structures, branching structures, array manipulation, solving systems of linear equations and polynomial regression, etc. The class meets twice a week, 50 minutes per class. Enrollment is limited to 25 people per section. In the fall of 2014, the flipped classroom approach was implemented in the CS221 course. A total of 40 students were enrolled in two sections. Almost all the students did not any prior programming experience. Prior to the fall of 2014, the course had been taught using the traditional lecture method.

To implement the flipped classroom approach, the author created a total of 48 videos using Camtasia Studio and a Tablet PC. Videos were limited to 3 to 10 minutes. Each video comprised audio of the instructor explaining the material and live screen captures. The videos were posted on the learning management system "Blackboard" and accessible to students. Students were expected to watch the video lectures prior coming to the class.

Each class meeting consisted of three sections. At the beginning of each meeting was a 5-minute question-and-answer session over the material covered in the videos. That was followed by a 5-10 minute quiz section which was designed to provide incentive for students to watch the videos and opportunities for the instructor to catch common misconceptions. The majority of the class meeting time, about 35 minutes, was spent on interactive learning activities. The in-class activities consisted of 3 to 5 assignments with increasing level of difficulty. Students could work independently or in small groups. Instructor was available during the class to provide individualized or small group guidance. Students were required to submit their in-class assignments before leaving the classroom.

Results and Discussion

Of the 40 students enrolled in the course, 95% were male, 100% were white, and 100% were traditional students. To understand students' perceptions of the flipped classroom approach, a brief survey was administered in the middle of the semester and student evaluation of the course was conducted at the end of the semester. Figure 1 indicates that out of the 37 students who took the survey, majority students (86%) wanted to continue with the flipped classroom approach. Figure 2 illustrates that almost all the students (92%) agreed that the quizzes at the beginning of each class motivated them to complete watching the videos before coming to the class.

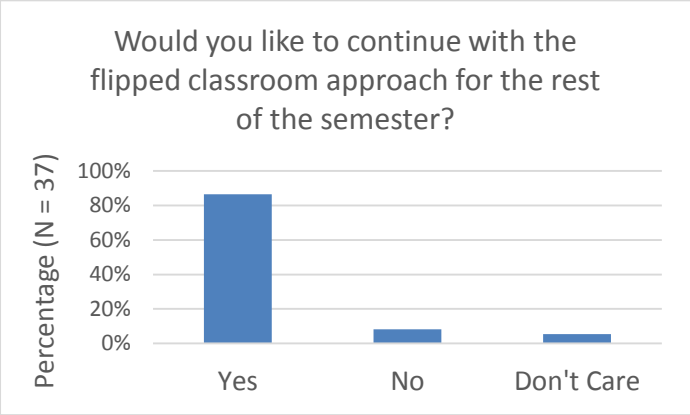

Figure 1: Student responses to the survey question regarding teaching method for the rest of the semester

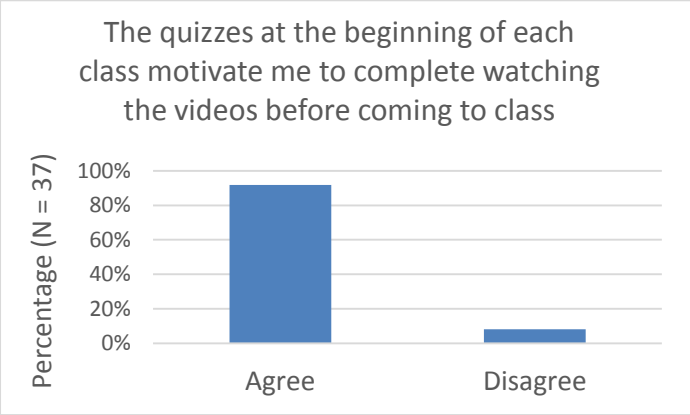

Figure 2: Student responses to the survey question regarding the effectiveness of the quizzes

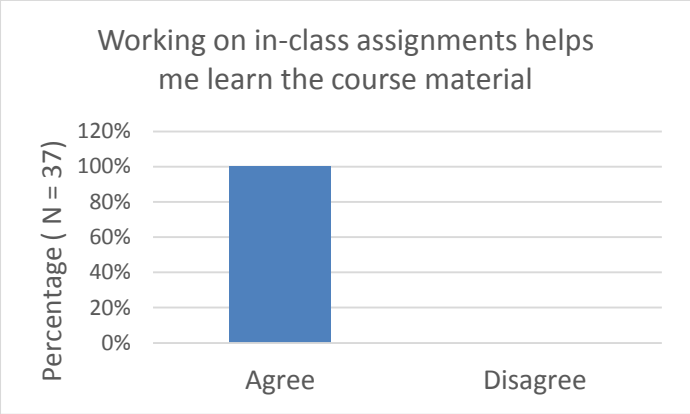

Figure 3: Student responses to the survey question regarding the effectiveness of the in-class assignments

Figure 3 reveals that all the students felt that the in-class activities were indeed helpful to their understanding of the material. Figure 4 shows that 43% of the students frequently watched the videos for multiple times, 43% rarely watched, and 14% never watched the videos more than one time.

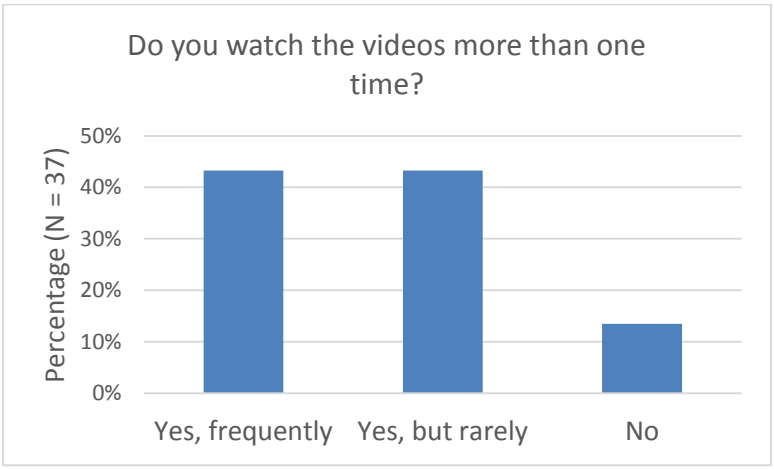

Figure 4: Student responses to the survey question regarding how often they watched the videos

Students made both positive and negative comments on the flipped method at the end of the semester. Some of the comments are as follows:

- "*I like the process of watching the videos before class then taking quiz on the material the next day. This gives me a lot of time to review the material on my own. This to me is the best way to learn in this type of class*"
- "*I personally enjoyed the flipped learning style where assignments were performed in class and lectures were watched at home via videos*"

- "*Could explain better in class. Quizzes are very specific. If a small mistake you get wrong*"

Because the class offered in the fall of 2013 (lecture-based teaching) and in the fall of 2014 (flipped classroom) was taught by the same person and covered the same topics, it offered an opportunity to evaluate the effectiveness of the flipped class approach on student learning. Identical final exams were used in these two semesters and they were graded by the same person using the same rubric. A comparison of students' final exam grades in the non-flipped and flipped courses is displayed in Figure 5. The flipped section yielded much more A's (48% vs. 24%), less B's (43% vs. 56%), and less C's (8% vs. 16%).

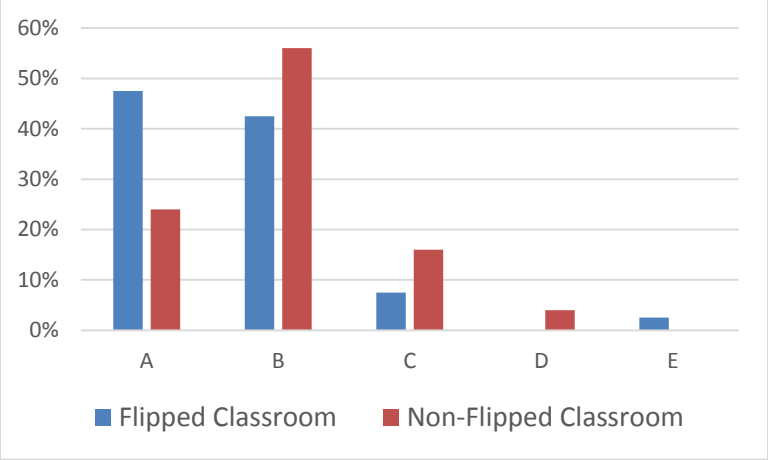

Figure 5: Comparison of grade distribution between flipped (n = 40) and non-flipped course (n = 25) sections

Although more students received A's or B's in the flipped section, a closer examination on the final exam scores, as shown in Table 1, reveals that students did better on the Excel part, but did worse on the MATLAB part.

Table 1: Average Student Performance on the Identical Final Exam

	Fall 2013	Fall 2014
Excel Average	36.2	40.9
MATLAB Average	41.4	34.5
Total	77.6	75.4

Blackboard statistics tracking function allowed the instructor to run a report and view detailed information about the usage of video lectures, including how many times a video was viewed by students and when it was accessed.

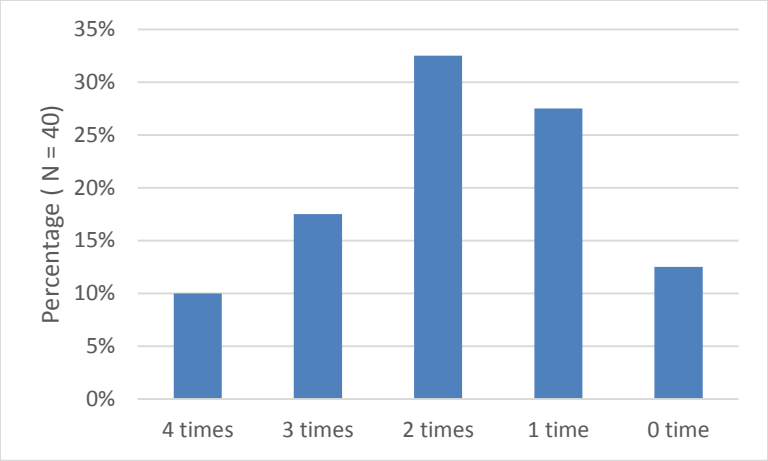

Figure 6: Statics tracking report of the number of times an Excel video was viewed by students

Figure 6 displays the statistics tracking report of an Excel video on the topic of solving linear equations. The majority of students (61%) watched the videos more than one time, 28% watched once, and 13% never watched the video. This report also shows that this video was viewed 74 times at the time the topic was introduced in September and was viewed 33 times in December before the final exam. But unlike the Excel videos, the statics tracking report of the usage of a MATLAB for loop video revealed that the majority of the students (68%) only watched the video once, 28% of the students watched the videos more than once, as shown in Figure 7.

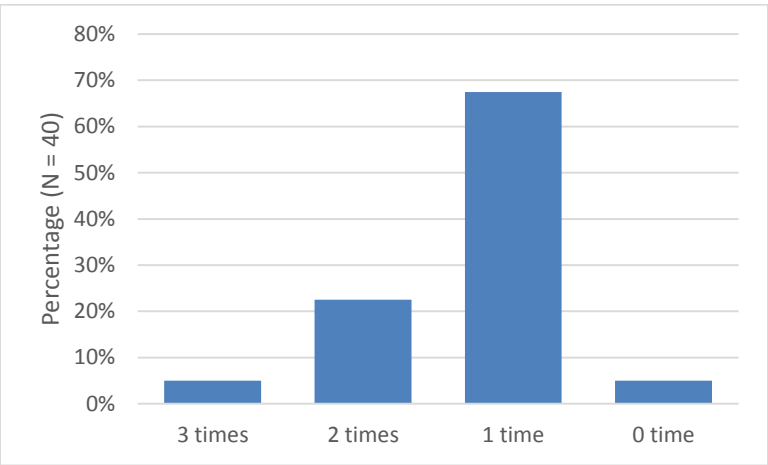

Figure 7: Statics tracking report on the number of times a MATLAB video was viewed by students

The discrepancy between Excel results and MATLAB results is primarily due to the availability of the software. Students can get Office 365 for free, so they can practice the Excel examples when they watched the videos at home. In contrast, the MATLAB is expensive, costing $99 for the student version, so most students did not have MATLAB installed on their personal computers at home. Just watching the video without practicing any of the examples made

students less engaged and harder to fully understand the material. As the semester got busier, less motivated students may forget to practice the MATLAB problems at a school computer lab before coming to lecture, so they came to class unprepared.

Conclusions

The flipped classroom experiment in the engineering computation course has changed most students' expectations on how a course should be taught. With the flipped classroom, students have shifted from passive recipients of knowledge to active constructors of knowledge. Student feedback about the flipped classroom model is generally positive. Most of the students have taken the advantage of online video lectures and watched the videos multiple times. The flipped classroom approach seems particularly well suited for teaching Excel. One possible way to solve the unavailability of MATLAB at home is to use the MATLAB alternative Octave. The Octave language is quite similar to MATLAB and it is free.

Flipped classroom approach is not simple and it is hard to be perfect in its first implementation. Continuous improvements and modifications are needed to maximize the advantages of using this novel approach for student learning[7]. In the fall of 2015, the author plans to modify the course from a flipped class to a semi-flipped class[8]. Students will still watch the videos before coming to the class, but each topic will be introduced briefly in the classroom by instructor and students working on related examples together. The quiz and in-class activities sections will be kept the same.

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