Results and Observations from Two Semesters of Implementing a Flipped Classroom Model in an Engineering Computation Course

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Abstract

The flipped classroom model has been implemented in a sophomore level engineering computation course at West Kentucky Community and Technical College. In three consecutive years, this course was taught in different approaches: in the fall of 2013, the traditional lecture format; in the fall of 2014, the fully flipped classroom model; and in the fall of 2015, the partially flipped classroom model. This paper describes the methodologies of implementing the flipped classroom model in this class and the motivations to modify the fully flipped model with a blended, partially flipped model. Details on course design, online video preparation, and student attitudes toward the flipped classroom are presented. Overall, the flipped classroom model has positive impact on student learning. Results from assessments and feedback show that students are generally in favor of the flipped classroom model over the traditional lecture format. In the flipped classroom, students perform better on exams and take on greater responsibility for their learning.

Keywords

Active learning, Flipped classroom, Partially flipped classroom, Engineering computation

Introduction

Engaging students in lectures through active learning has been demonstrated to effectively improve students' thinking and problem solving skills[1]. According to Felder and Brent, active learning is defined as "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes"[2]. Active learning includes a variety of instructional techniques, among which think-pair-share, concept tests, and thinking-aloud pair problem solving are particularly effective ones[2]. Recently, a new pedagogical method, the flipped classroom, has been gaining attention and adherents within the educational community, particularly in STEM higher education. As the name implies, the flipped classroom reverses the traditional lecture and homework elements of a course. In a typical flipped classroom, instructors create lecture videos or voice-over PowerPoint slides that allow students to watch outside of the classroom on their own time before coming to class. The class time is then used to help students practice and apply the knowledge from the lecture videos in an environment where students can receive immediate feedback.

Many researchers have reported on their experiences with the use of the flipped classroom approach. Day and Foley[3] conducted their study in a computer interaction course and reported that students in the flipped classroom scored significantly higher on the homework assignments, projects and tests. Redekopp and Ragusa[4] 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.[5] implemented the flipped classroom strategy in three distinct engineering courses and one of their findings was that students were better prepared for class. Bland[6] reported that the flipped classroom approach actually allowed more content to be covered in a course. He et al.[7] 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[8] found that the flipped classroom model helped students develop an awareness about the importance of self-learning and take responsibility for their own learning.

This paper presents the results of a two-semester study on the use of the flipped classroom pedagogical approach in an engineering computation course at West Kentucky Community and Technical College. The methodologies for using different instructional approaches: the traditional lecture, the fully flipped classroom, and the partially flipped classroom, are described. Assessment data are collected to examine the effectiveness of the flipped classroom approaches. Student and faculty perceptions of the flipped classroom model are also presented.

Methods

The course examined in the study is a sophomore-level engineering computation course, CS221-First Course in Computer Science for Engineers. This course serves as an introduction to the fundamentals of numerical analysis as applied to engineering problems and to structured programming. It also provides students with the necessary knowledge and skills to solve engineering problems by using modern computational techniques and tools, namely Excel and MATLAB. 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 period. Enrollment is limited to 25 students per section.

Traditional lecture approach

Prior to the fall of 2014, the course was taught exclusively by using the traditional lecture method, with roughly three-fourths of a typical class meeting period devoted to a lecture and the rest to solving example problems using computers. Since the class was primarily oriented towards lecturing, it was difficult to find the time to implement active learning activities in the class. It was also found that students were not fully engaged during lectures in a computer lab setting since they were easily distracted to the news and entertainment sites, social media, and video games. Furthermore, due to the fact that students learn in different ways and at different paces, the instructor and majority of the students sometimes had to wait for some particular students to catch up when working on examples or tutorials.

Fully flipped classroom approach

In the fall of 2014, a fully flipped classroom approach was implemented in the CS221 course. A total of 40 students were enrolled in two sections. Almost none of the students had any prior

programming experience. The instructor created a total of 48 lecture videos using Camtasia Studio and a Tablet PC. Each video was about 3 to 10 minutes, comprised of the audios 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 to coming to class. Each class meeting was divided into three sessions. It started with a 5-minute question-and-answer session over the materials covered in the videos. That was followed by a 5-10 minute quiz session which was designed to provide incentive for students to watch the videos and opportunities for the instructor to catch common misconceptions. The final session, 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 increased level of difficulty. Students could work on the activities either independently or in small groups. Instructor was available during the class to provide individualized or small group guidance.

Partially flipped classroom approach

After one semester implementing the fully flipped classroom method, a decision was made to make some changes in the next offering of the course. The major concern was that not all students took responsibility for their own learning. Some students did not watch the lecture videos in advance and thus received zero grades on the quizzes. Those students were often clueless in problem solving session. Therefore, it was very difficult for unprepared students to succeed in a fully flipped classroom approach. The other issue was about the quizzes conducted in class. The closed-book, closed-notes quizzes could only be taken once. Students often found it hard to fully understand and digest all the critical concepts from the lecture videos viewed a day before the quiz. Some students watched the videos in greater depth but still received low quiz grades, and became frustrated since the quiz grades counted 20% of the course grade.

Based on all those concerns, a partially flipped classroom approach was implemented in the CS221 course in the fall of 2015. The class consisted of two sections with a total enrollment of 30 students. In this partially flipped approach, the videos were still available for students to watch prior to the class time. However, the main topics were further discussed in the live classroom, by working on extra problems led by the instructor in eight-minute face-to-face lectures. Additional change made in this blended approach was that the quizzes were handled differently. The un-proctored quizzes were administered via Blackboard. Students could take the quizzes any time after they finished watching the lecture videos but had to complete the quizzes 5 minutes before class began. To prevent students from sharing the correct quiz answers, students were not able to see their grades until the quizzes became unavailable once the class has started. The quizzes could be taken for multiple times and the grade for the last attempt was counted.

Results and Discussion

Of the 40 students enrolled in the fall semester of 2014, 95% were male, 100% were white, and 100% were traditional students. Of the 30 students enrolled in the fall semester of 2015, 87% were male, 97% were white, and 100% were traditional students. To understand students' perceptions of the flipped classroom approach (fully flipped and partially flipped), survey was

administered in the middle of each semester. Results are summarized in Figures 1-5. Figure 1 indicates that out of the 37 students (92.5% of the course enrollment) who took the survey in the fall of 2014 and 27 students (90% of the course enrollment) who took the survey in the fall of 2015, the majority of the students (86% and 63% for 2014 and 2015, respectively) wanted to continue with the flipped classroom approach. Only 8% from the fall 2014 group and 4% from the fall 2015 group opposed the flipped approach. 26% from the fall 2015 group had no preferences for teaching methods. Perhaps students in this group were confident that they could learn the course materials well in either the flipped classroom or the traditional classroom.

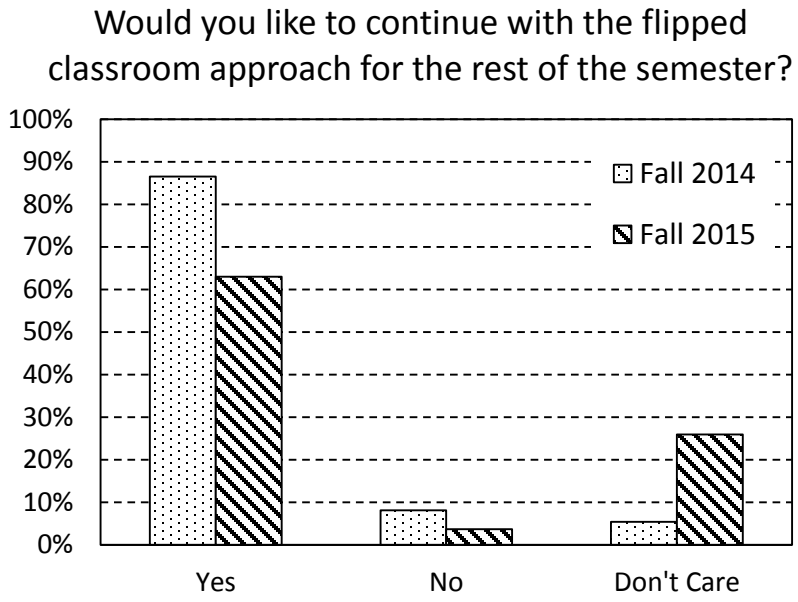

Figure 1: Student responses to the survey question regarding the teaching method used in the class

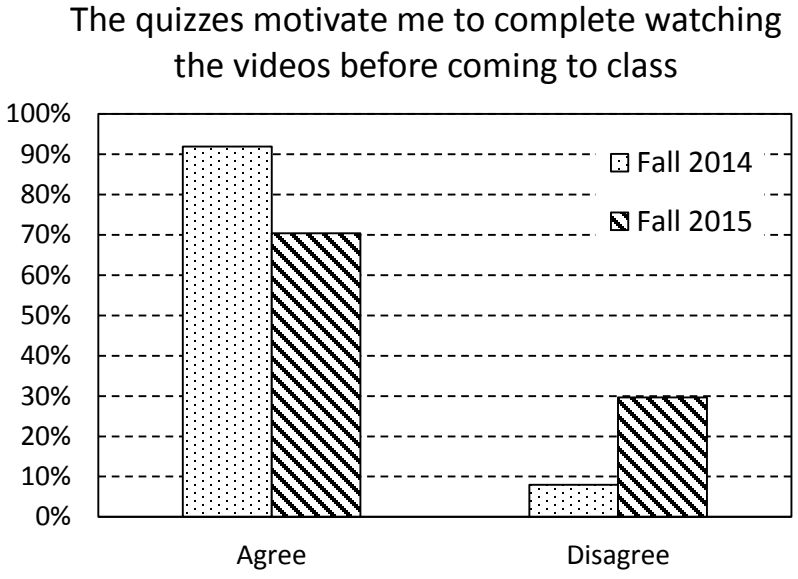

Figure 2: Student responses to the survey question regarding the effectiveness of the quizzes

Figure 2 illustrates that the majority of the students (92% and 70% for 2014 and 2015, respectively) agreed that having quizzes was a motivational factor for watching the videos. Figure 3 reveals that all the students felt that the in-class active learning activities were indeed helpful to their understanding of the course material. Figure 4 shows that 43% (fall 2014) and 30% (fall 2015) of the students frequently watched the videos for multiple times while 43% (fall 2014) and 48% (fall 2015) rarely watched the videos more than one time.

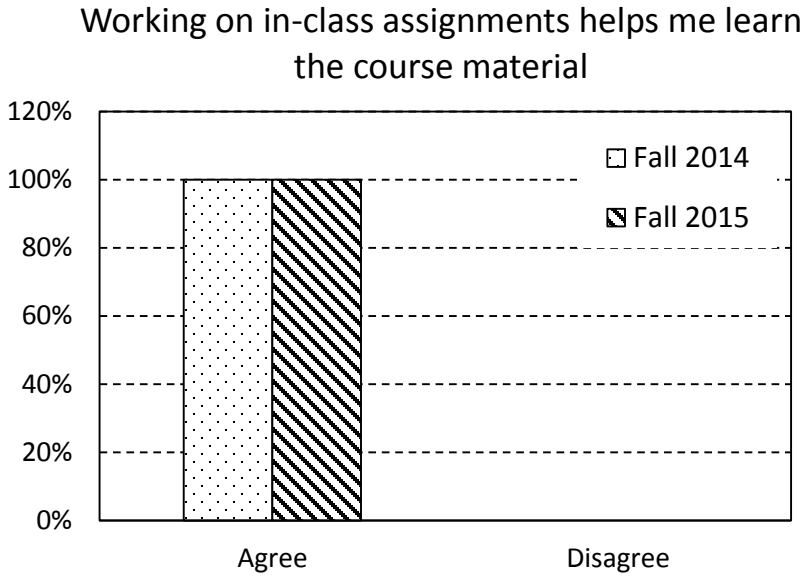

Figure 3: Student responses to the survey question regarding the effectiveness of the in-class assignments

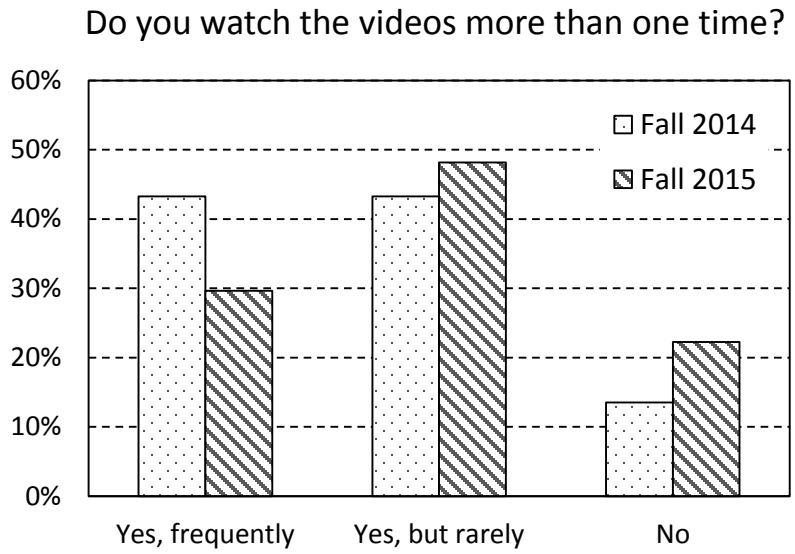

Figure 4: Student responses to the survey question regarding how often they watched the videos

The students enrolled in the fall of 2015 were asked whether the 8-minute face-to-face lectures in the live classroom were necessary. As seen in Figure 5, almost 90% of the students (24 out of 27 students) thought that the mini-lectures were helpful.

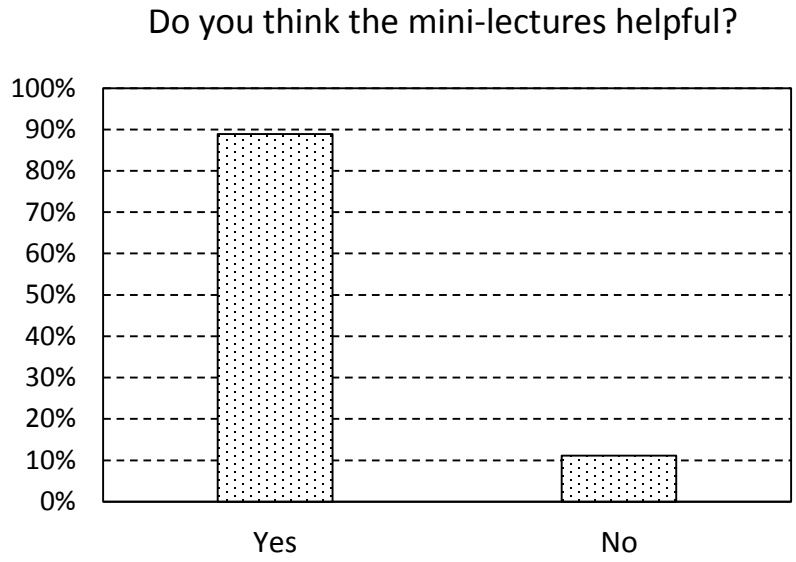

Figure 5: Student responses to the survey question regarding the effectiveness of the mini-lectures

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

- *"I enjoy the class setup with the online videos"*
- "*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*"
- *"I like learning in class but need the videos also"*
- *"Videos are great because not everybody works at the same pace"*
- "*Could explain better in class. Quizzes are very specific. If a small mistake you get wrong*"

Because the course offered in the fall of 2013 (traditional lecture format), in the fall of 2014 (fully flipped classroom), and in the fall of 2015 (partially flipped classroom) was taught by the same instructor and covered the same topics, it offered an opportunity to evaluate the effectiveness of the flipped class approach on student learning. Similar exams were used in these three semesters and they were graded by the same instructor using the same rubric. Also the exams were never returned to students, so the contents had been kept confidential. A comparison of students' final exam grades over these three semesters is displayed in Figure 6.

The partially flipped classroom yielded much more A's (61%), as compared to the fully flipped classroom (48%) and to the traditional lecture format (24%). Overall, more students received A's or B's from the flipped classrooms (fully flipped 91% and partially flipped 93%) than those from the traditional lectures (80%).

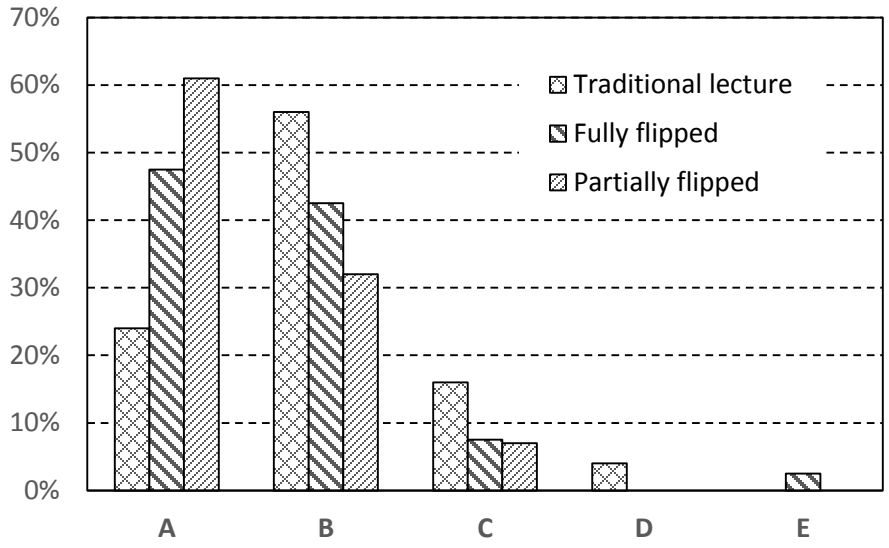

Figure 6: Comparison of exam grades for students from the traditional lecture, the fully flipped classroom, and the partially flipped classroom

The averages of the exam scores, as shown in Table 1, reveal that students performed slightly better in the partially flipped classrooms.

Table 1: Summary of Student Performance on the Identical Final Exam

	Fall 2013 Traditional lecture N=25	Fall 2014 Fully flipped N=39	Fall 2015 Partially flipped N=28
Mean	77.6	75.36	78.14
Std. Deviation	9.535	10.574	10.596

The statistics tracking function in Blackboard 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 7 displays the statistics tracking report of an Excel video on the topic of solving linear equations. The majority of the students (61%)

watched the videos more than one time, 28% of the students watched once, and 13% of the students never watched the video. This report also shows that this video was viewed 74 times at the time the topic was introduced in September 2014 and was viewed 33 times in December 2014 before the final exam.

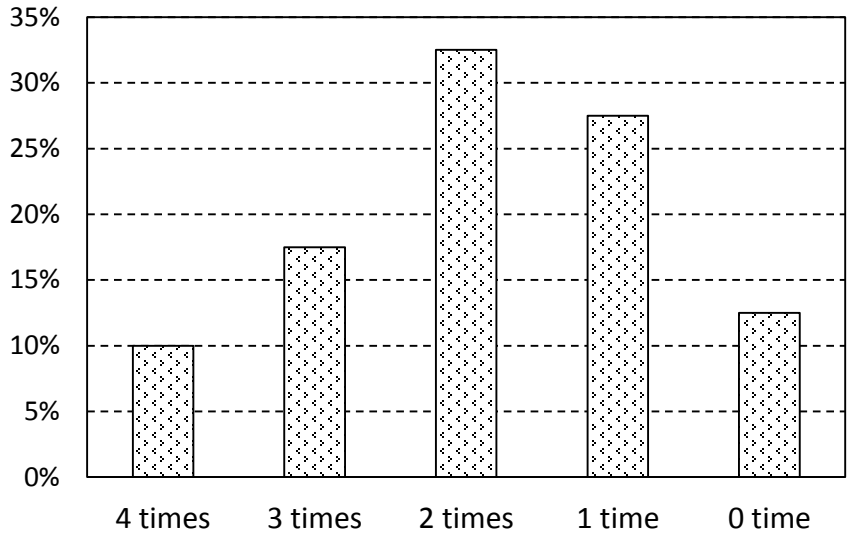

Figure 7: Statistics tracking report on the frequency of viewing an Excel video lecture

To evaluate whether the in-class active learning activities improved students' critical thinking and problem solving skills, the instructor compared the pre-and post- in-class activities quiz grades. Figure 8 shows the comparison of the quiz results on the topic of MATLAB function file. Only 38% of the students got the correct answer by just watching the lecture videos before class. Without knowing the correct answer to the quiz problem, students came to class, participated in the active learning activities, and took the same quiz again at the end of the class meeting period. Figure 8 shows that 86% got the correct answer.

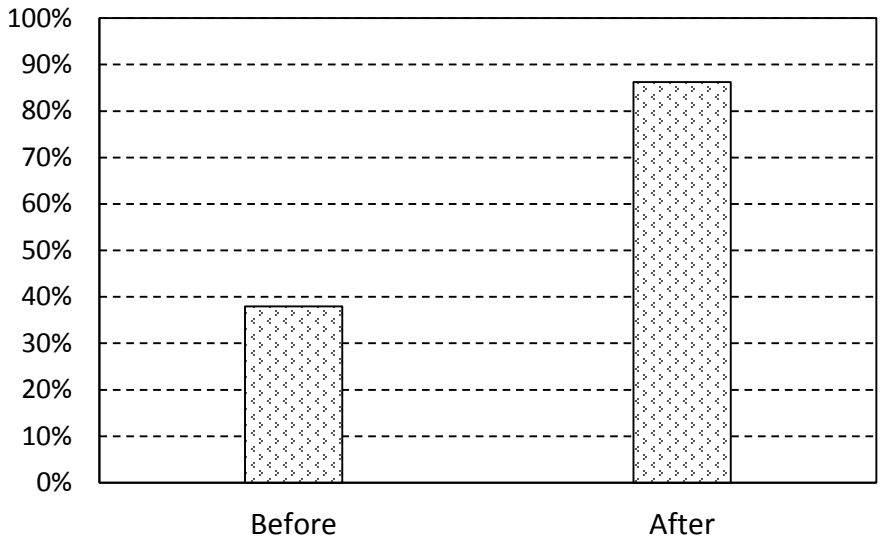

Figure 8: Comparison of the pre- and post- in-class activities quiz results

Conclusions

Over the past three consecutive years, three different instructional approaches have been implemented in a sophomore level engineering computation course, namely the traditional lecture, the fully flipped classroom, and the partially flipped classroom. Overall, the flipped classroom model has shown positive impact on student learning. With the flipped classroom, students have shifted from passive recipients of knowledge to active constructors of knowledge. Most of the students have taken the advantage of online video lectures and watched them for multiple times. Between the two flipped classroom methods, the partially flipped model helps the students better in learning and understanding the lecture contents. It further provides opportunities for reviewing important concepts covered in the lecture videos and for students to ask questions.

Results from assessments and feedbacks have shown that students generally favor the flipped classroom model over the traditional lecture format. Students score slightly better in the flipped classroom than students in the traditional classroom. The biggest challenge for instructors to implement a flipped classroom model is to get all students to watch the lecture videos before coming to class, so self-motivation is the key factor in student success with the flipped classroom approach.

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