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Flipped Classroom Increases Achievement of Student Learning Outcomes

Claire Komives,

Biomedical, Chemical and Materials Engineering
San Jose State University
One Washington Square
San Jose, CA 95192-0082
USA
Claire.Komives@sjsu.edu

Abstract: The Chemical Engineering Program at San José State University (San José, CA USA) experienced a dramatic increase in students starting in Fall of 2014. From 1999 to 2013, approximately 20-25 students graduated from the program each year, but since 2014 there have been over 100 beginning the junior year. In addition, the faculty have observed that students' attention spans, on average, have decreased, in agreement with literature assessments. After giving the Effective Teaching Workshop at Thiagarajar College of Engineering in 2016, the classroom protocol of the Industrial Chemical Calculations Course was modified to include watching the lectures on video prior to the class.Not giving lectures during the class period allowed more time in class to have students practice solving problems. The result has been an increase in student participation in class even with the large number of students, as well as an increase in the achievement of student learning outcomes. This paper will discuss the logistics of the flipped classroom and a presentation of evidence of improved student learning.

Keywords: Flipped Classroom, Learning Outcomes Achievement, Large Class Size

Claire Komives
Biomedical, Chemical and Materials Engineering
San Jose State University
USA
Claire.Komives@sjsu.edu

1. Introduction

The flipped classroom was introduced in the early 2000's as a way to enable students to follow the lectures according to their own schedule and at their own pace. As of 2013when the article was published there was no definite evidence that student learning was improved by the strategy. More recently, it was also concluded that while it is possible to articulate in what ways, theoretically,the flipped classroom approach can help students, there is still no conclusive evidence that it can be effective for increased learning. One of the advantages of the strategy is to enable the in-class time to be spent doing active learning activities. Indeed, one study suggested that comparing two courses where the active learning was implemented equally with one incorporating traditional lecture and the second one a flipped class, no difference was found in achievement of the learning outcomes.

My motivation to begin using the flipped classroom was mainly that I observed that students in the class, after hearing my lecture and appearing to be engaged and participating, were unable to solve problems incorporating information from the lecture. In fact, it often appeared that they learned absolutely nothing from the lecture. As such, it seemed that putting the lectures on video would allow more in class time to focus on problem solving. The final motivation to switch to flipped classroom was the significant increase in number of students. We used to have a five hour per week class protocol with one two hour lecture and one three hour calculation period but with the increase in students and shortage of faculty, we had to shorten the class to two 75 minute class periods each week.

The flipped approach was taken in a junior level Industrial Chemical Calculations course (CHE 115) which is called material and energy balances in other schools. The course involves no complex mathematics only algebra and a miniscule amount of calculus. Students have a difficult time solving the problems, especially at the beginning of their learning, due to the long problem statements and need to translate the information from the problem statement to flow chart and equations, and also identifying solution strategies for the problems.

2. Methodology

Videos were recorded using a Samsung Galaxy TabPro S with Camtasia software. All lectures were PowerPoint presentations that are also available to the students in a course reader that can be purchased. The lectures include explanations of principles as well as solutionsto some problems. Videos were uploaded to YouTube under the PackersClaire channel and then connected into Canvas learning management system software. Also uploaded to Canvas are the in-class problem solutions, homework and exam solutions. Homework and in-class quizzes are given and are returned during the time the students work on problems in the classroom. This method of passing the papers was chosen as a way to learn the names of the students and increase professor-student interaction. In-class activities include Think-Aloud-Paired-Problem-Solving of relatively complex calculations as well as group problem solving and individual problem solving. The multiple problem solving strategy approach is designed to help students with different learning styles learn to solve problems and also increase their communication skills by learning to articulate the details of the problem solution with their group mates. This strategy is incorporated in all of the courses in our program, and enables us to help students develop their critical thinking skills.

1) Ineffective approach The first year, complete lectures were recorded as one video and at the end of the lecture the students were assigned a problem related to the material on the video but different in some way from the problem(s) shown in the lecture. The students were to hand in the problems at the beginning of the class on paper. There was no way to determine if the students actually watched the videos except by the YouTube views count. The YouTube counts also included some viewers from outside the university. In the class period, the lectures were repeated but basic sections were skipped. The thought was that students could ask questions on sections that were not clear, and there was still plenty of time for in-class problem solving. At the beginning of each lecture, multiple choice questions were posed to serve as a review of previous lecture material done in a think-pair-share format. Students then voted for the correct answer by raising the hand.

2) Effective approach: The second year the lectures were broken down to short segments of 10-15 minutes each and an on-line quiz was posted on Canvas with numerical answers that could be automatically graded. Quizzes included both simple plug-and-chug calculations as well as complete process calculation problems. This time the lectures were not repeated but the solutions to the quiz problems were shown. Once again, at the beginning of each lecture, multiple choice questions were posed in a think-pair-share format. Students then voted for the correct answer using iClickers.

3. Results

The first year some positive outcomes were noticed, but it was not observed that the students actually were learning better than in previous years. It is difficult to analyse the effectiveness of the approach over multiple years because the preparation and skills of students has changed over time. About 20% of the students failed the course in 2016 and had to repeat, and those students are currently retaking the course. The repeating students make up about 20% of the population in the class. It is notable that the 20% failure rate in 2016 was higher than in previous years. Students were generally happier than in previous years as noted on the course evaluations. The only negative comment on the evaluations was that the exams were too long and too hard. In fact, due to reduced class time, students only had 75 minutes to take the tests. From the first year experience, it was determined that the videos were probably too long and the problems assigned were too complex for the students which resulted in many of the students either copying the solutions or not doing them at all.

The strategy of the second year is currently underway but already some evidence is clear of the success of the strategy. The average score on the quizzes to date in the class is greater than 90%, whereas in year one the average of the quiz scores was 75%. The problems are of equivalent difficulty this year as last year. A second piece of evidence of improvement is the level of class participation. On the order of 50% of students ask questions in the class whereas last year only about five students (~10%) asked questions and always the same ones asking. This year the class is more of a dialog during the review of the problems and during the in-class problem solving many students ask questions.

Assessment of student learning outcomes is carried out in the class relevant to the first ABET outcome:

(a) an ability to apply knowledge of mathematics, science, and engineering.

The performance criteria used in the CHE 115 class for assessment of the ABET outcome include:

Students can analyse systems through material and energy balance models.

Midterm and final exam problems are used to determine the number of students that meet the acceptable criterion of 60% which is a C in the course. Exams are entirely problem solving as well as 5% of short answer question that asks a concept question at the level of evaluation. Evaluating problems through the course involving the solution of material and energy balances, the degree of attainment averaged over several midterm and final exam problems has dropped over the years from 60% in 2012 to 33% in 2016. The drop in outcome attainment correlated inversely with the increase in student numbers in the program.

Comparison of a similar problem from a midterm each year from 2015, when no flipped class approach was taken, 2016 when the long videos were used, to 2017 when

Table 1. Percentage of students meeting criterion of 60% on learning outcome by year the short videos were presented is shown in Table 1. The percentage of students who met the criterion of 60% on the problem shows the highest level of attainment was obtained in 2017 when the short video strategy was used.

Year	Percentage meeting criterion
2015	15.2
2016	15.9
2017	43.9

4. Discussion

Material and Energy Balances is considered to be a weed out course in spite of being relatively easy as compared with other courses in the Chemical Engineering curriculum such as Transport Phenomena and Thermodynamics. Although the mathematics is simpler in this course, the problem statements are long and have to be translated into equations and a flow diagram. Students have a lot of difficulty reading the problem statement and taking the necessary steps to solve the problems. The difficulty is often due to their struggling with English, since the program is more than 25% Hispanic, as well as large populations of Chinese, Middle Eastern, African, Vietnamese and other nationalities.

Based on the lack of success of in-class lectures, it seemed that using valuable class time for a lecture that the students seem to be unable to learn from, the lectures were moved to out-of-class preparation time. The lectures cover the information from the textbook distilled to the essential strategies for solving problems.Students still ask questions in class related to material on the videos, suggesting that they did not absorb all of the information. However, we spend the time in class doing problem solving and that is the goal of all of the learning outcomes.

According to Felder, every ten minutes in the class some active learning exercise should be scheduled . Based on the ten minute principle, the videos were shortened after the first year and problems have been assigned that can be automatically graded at the end of each section. It takes time to prepare the videos and quizzes but that time is invested in developing problems that are relevant to the sections of the lecture instead of processing reams of student work. Based on the participation rate of the video quizzes the students are motivated to solve the problems, even if they are not actually watching the videos.

Ideally, the same test would be given each year to make a better comparison of what has worked well and what has not worked well. Thus, the results of this exercise are still preliminary but enough evidence from these comparisons support the use of flipped class for teaching students problem solving in a basic engineering class.

Interestingly, after the first midterm in the course of 2017, some of the students in the class pleaded for lecture to help them learn the material, while others said if the lecture is the same as on the video then they are not interested in seeing the material for a second time. As a compromise, at the beginning of the class period one complex problem has been solved on the board, with a “let's think through this together” approach. The students again were very grateful for the approach, but it does not seem to be helping them above what was learned in previous years. Even solving a problem on the board, while it is easier for the students to watch the problem being solved, does not appear to help them more than if they do the problem solving themselves. It is difficult for students to accept that a change in the approach to active learning is much better for their educational advance.

As described in Felder, we can do our best to reach as many of the students as possible, but it is likely that we will not reach them all. Ultimately, the students that put the best effort to not only try to learn the material but also reflect on what they need to do to succeed will achieve their success. New strategies for motivating the students to work hard both in and outside of class are needed.

5. Conclusion

Implementation of flipped classroom strategy for a junior level core course in Chemical Engineering has been shown to increase the level of student learning based on preliminary grades in quizzes as well as observation that students are more engaged during the class periods. Shortening the lectures to 10-15 minutes and adding on-line quiz problems has motivated the students to learn the material at an increased level as compared with in-class lectures. The increase in class time available for problem solving in groups enables more students to learn to solve problems and increases their communication skills.

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