A ”flipped” statics classroom

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Abstract

Many courses across the curriculum in secondary and post-secondary education are moving to the so-called "flipped" classroom. In the "flipped" classroom model students survey the course content online before class then class time is spent discussing and solving problems with the guidance of the instructor. The theory of the "flipped" classroom is that students are actively engaged during class with the instructor and other students, thus increasing comprehension of the course material. This paper considers a "flipped" classroom in a university calculus-based engineering statics course. The specific structure of this class was to place recorded videos of lectures, as well as videos of solved problems, online for students to view prior to attending class. Class time was then devoted to a combination of instructor-guided problem solving as well as student-led problem solving. The intention of this approach was to move the concept derivations (which students often discount) out of class time and replace it with more example problems that students directly work to solve with instructor support. The expectation is that students will have more confidence and success in solving statics problems in the future. This research considered in this paper occurred over the course of two semesters with two distinct groups of students. Both qualitative and quantitative assessments were completed during both semesters including student performance on Fundamentals of Engineering exam questions, student surveys, and instructor observations. Modifications were made to the delivery of the course both mid-semester and between semesters based on the results of these assessments. The results of these assessments, as well as the ultimate framework of course, are detailed in this paper.

Introduction

In the "flipped" classroom, the traditional lecture material is presented in advance of class, typically using online videos. Class meetings are used for student-centered discussion and problem solving. In theory, this approach yields more active classes where students are applying the course material thus leading to increased comprehension. This paper considers a "flipped" classroom in a university calculus-based engineering statics course.

Bishop and Verleger[1] presented a thorough survey of research on the "flipped" classroom at 2013 American Society for Engineering Education Annual Conference in Atlanta, Georgia. Their work reviewed over 100 sources about the "flipped" classroom including journal articles, news articles, and websites. Their exhaustive work found that students' perceptions on this approach are mixed. Students were apprehensive with regards to video lectures, but preferred the interactive classes. Qualitative results suggest improvement in student learning; however, little objective research has been done regarding student learning in a "flipped" classroom.

Some work has also been done on the "flipped" classroom in college-level engineering mechanics courses. Papadopoulos and Santiago[2] considered an inverted classroom in a statics course. They found instructors favored the inverted approach while students' perceptions were somewhat mixed. In this initial research, they found improvement in scores over standard approaches, but stated more data is needed to achieve more conclusive results. Swithenbank and

DeNucci[3] found that flipping a dynamics class showed some evidence of positive outcomes; however, they suggested a more detailed study would be necessary to gather definitive data. Thomas and Philpot[4] worked to create a framework for a "flipped" mechanics of materials class which included the ability to measure student performance on a variety of topics in order to alter instruction to the needs of students. Future research will be focused on improving the instruction. Cavalli, et al.[5] "flipped" four different courses including an engineering mechanics course and found positive attitudes towards the approach, but mixed results in student performance. Swartz, et al.[6] also "flipped" several civil engineering courses including a mechanics course and discussed the perspectives of the instructors. They found that faculty appreciated the flexibility of class time and felt the students were more engaged during class. They did not present the performance of the students in their research. All of these studies that considered "flipped" engineering mechanics courses found results similar to those found in the exhaustive study by Bishop and Verleger[1] in that the initial results showed promise qualitatively, but more research was needed to conclusively determine the effectiveness on student performance.

This paper will begin with a discussion of the initial "flipped" course design followed by the results from the first offering of the course. The revisions made to the course prior to the second offering will then be detailed followed the results from that second offering. Finally, some conclusions regarding the "flipped" statics classroom will be made.

Initial course design

The statics course considered here is part of a typical calculus-based engineering mechanics sequence. Topics in the course include force and moment vectors, equilibrium, structural analysis, friction, centroids, and moments of inertia. The class meets three times a week for 50 minutes over 15 weeks. The course has weekly assignments, four unit exams, a final exam, and a design project. Some small changes were made to this outline in order to accommodate "flipping" the class as detailed below.

A learning management website was utilized to "flip" the statics course. The course site consisted of videos and notes to be viewed by students before class. It also contained assignments and student grades. Students obtained course material from this site, the required textbook, and information given during class meetings.

For the "flipped" statics course, students were to watch two online videos before each class. One video was a brief lecture introducing the concepts of the topic. The other video was an example problem solved by the instructor. The videos were computer screen recordings of a presentation with audio of the instructor detailing the material being presented. The lecture videos ranged in length from 4 minutes to 9 minutes and the example problem videos ranged from 3 minutes to 7 minutes.

Each 50-minute class meeting consisted of four example problems given to students. The instructor worked out the first two problems on the board for the students. The students were expected to complete the other two problems during class. Students could work together on these problems and ask questions of the instructor. The idea was to get students working the

problems themselves in order to solidify their comprehension of the material. As detailed below, this course structure changed during the semester due to student response and performance.

Results from first offering

The "flipped" course structure changed twice during the first offering. The first change came following the first exam. Student performance on this exam was below expectations, but nothing alarming. The change mainly came from student feedback suggesting it was too difficult to complete their two in-class problems having just been presented the topic in the same class. This led to changing the course structure so that videos were to be watched for two of the class meetings each week. In these classes, the instructor spent the entire 50 minutes working example problems at the board for students. The third class each week was devoted to students solving four problems on their own with help from each other and the instructor. This class meeting was referred to as a problem day.

The second change in the structure of the course occurred after the second exam, which was an unmitigated disaster. Over half of the students in the course received a grade of D or F on this exam. The instructor noticed some things that likely caused this issue. Generally, students were not watching the videos, thus coming to class ill-prepared to effectively follow the solving of example problems. In addition, students were using the class problem days to work on homework rather than the problems given during the class. Without knowledge of the course material and little practice solving problems, students were not equipped to succeed in the course. In order to encourage students to do the work asked of them by the instructor, graded credit was given for watching the videos and completing the in-class example problems. Linking these activities to a grade caused students to do the work, thus improving their performance in the rest of the course.

In order to determine if the "flipped" course actually improved student learning, final exam scores from the first offering were compared with the final exam scores from the five previous semesters the course was taught by the instructor. For standardization, the final exam consisted of questions taken from the Fundamentals of Engineering Exam. Table 1 shows the average scores (out of 100) and standard deviations from the first "flipped" offering as well the previous offerings from the instructor. As can be seen, the average score was essentially unchanged between the two groups going from 82.8 to 82.7. The standard deviations were also pretty similar in both groups. While these results suggest the "flipped" course had little effect on student performance, it should be noted the relatively small number of students may not give significant results.

Table 1: Final exam scores for first "flipped" course offering

	Previous 5 semesters	1st "flipped" course
Number of Students	53	13
Average Score	82.8	82.7
Standard Deviation	11.1	9.7

At the end of the course, a survey was given to students to get their feedback on the "flipped" course structure. The survey consisted of seven questions on a five-point Likert scale regarding the course structure. It also consisted of three open-ended questions about the positives and negatives of the course. The perceptions of students regarding the "flipped" classroom were mixed. Some students thought the videos were helpful, while other students felt the lecture videos were somewhat hard to follow. Those that liked the videos stated the ability to review the videos later was the most helpful part. The greatest variance in student feedback was with the problem days. It seemed students either loved or hated these class days. The survey question asking if the problem days were helpful had the largest standard deviation of all survey questions. The most common suggestion offered by students in the open-ended portion of the survey was to include more videos of example problems. Based on the results from this survey, changes were made to the course as outlined below.

Course revisions

The primary structure of the course remained unchanged for the second course offering. The second offering included attaching student grades to watching the online videos and problem days which changed mid-semester during the first offering. Based on the student feedback as well as the observations of the instructor, two main revisions to the course were made before the second offering. The first addition was an extra video of a solved example problem for each topic. This increased the number of videos students were required to watch for each class to three. These video additions were in direct response to student requests. The other major revision to the second offering was the way problem days were facilitated. Students in the first offering seemed to dislike these classes and the instructor noticed students were not comprehending much from these days. During the first offering of the course, the in-class problems were given out and students worked on them quietly. The instructor only discussed the problems if specific questions were directly asked. In the second course offering, the problem days were more directed by the instructor. Students still worked on the problems themselves, but in addition the instructor give hints on the procedure of each problem gradually as the class progressed. This approach helped ensure students weren't falling too far behind and not attaining the expected outcomes from the class. The hope was that students would have better chance of completing all the problems, thus reinforcing their comprehension of the concepts.

Results from second offering

From the perspective of the instructor, the second offering was much improved over the initial offering. As expected, things went smoother having attempted the "flipped" course the previous semester. The changes implemented since the initial course design aided in keeping the instructor and the students on the same page. The graded credit given to students for watching the online videos continued to increase the view rate of the videos. In addition, the modification of the problem days was a definite improvement and led to a more cooperative classroom, exactly the purpose of the "flipped" classroom. The instructor became very comfortable with the "flipped" approach and observed some improvements over the traditional approach.

At the end of the course, students were given the same survey as the students in the first class to get their perspective on the "flipped" classroom. Student perceptions of the online lectures were similar to those from the initial offering in that the videos were sometimes difficult to follow. However, the improvements made to the problem days really seemed to resonate with students in a positive way. Specifically, one question in the survey asked students if they felt the "flipped" approach was an effective way to learn. The average response to this question was 4.1 on the 5-point Likert scale. This is compared to an average response of 3.7 on the same question in the first offering. This suggests that the changes made for the second offering improved students' perceptions and that, in general, students had a positive opinion of the "flipped" approach. The comments from the open-ended survey questions were supportive of the "flipped" classroom. One student summed their feelings of the course this way,

> "I think that the videos were perfect, not too long, but content filled. While a little hard to follow, I think that any new information would be as it is new. Afterwards though, the in class examples really helped to solidify this. The problem days were the best, a time to ask questions and I usually used this sheet for examples for the note sheet on the tests and the extra space to write any additional notes."

This response was representative of the comments given by other students. It should be noted that these perceptions are very similar to the results from extensive literature review done by Bishop and Verleger[1].

A similar final exam consisting of FE Exam questions was given at the end of the second course offering. The results of this exam are shown in Table 2 along with the scores from the first "flipped" offering and the previous traditional sections of the instructor. The average score in the second offering was 77.4 out of 100, a drop of more than 5 points over the traditional offerings. In addition, the standard deviation was more than 6 points greater than traditional offerings suggesting a wider range of student scores in the revised iteration. As stated earlier, the significance of these results should be downplayed given the small populations in these classes.

Table 2: Final exam scores of "flipped" classes and previous offerings

	Previous 5 semesters	1st "flipped" course	2nd "flipped" course	Total "flipped" courses
Number of Students	53	13	9	22
Average Score	82.8	82.7	77.4	80.5
Standard Deviation	11.1	9.7	17.8	13.5
			p-value	0.459

Also shown in Table 2 are the results of the two "flipped" courses combined. While the populations are still relatively small, combining the "flipped" sections offers a somewhat better comparison of the results. The combined average score is 2.3 points less than the traditional sections with a standard deviation 2.4 points greater. In addition, a t-test was performed comparing the final exam scores of the traditional sections and the combined "flipped" sections. This t-test resulted in a p-value of 0.459. Given that the p-value is greater than 0.05, the difference between the two populations is not statistically significant. Therefore, the "flipped" approach considered here has little significant effect on the performance of students.

Conclusions

This paper considered two permutations of a "flipped" statics course where lectures were presented as online videos to be viewed by students prior to class. Class meetings were used to solve example problems, both by the instructor as well as by students. Some issues with student compliance occurred in the first iteration leading to immediate revisions in the course structure. By the end of the first course students performed similarly to previous traditional course offerings; however, their perceptions on the course structure were somewhat mixed. Further changes were made before the second iteration of the course, especially to the student problem day which elevated students' opinions on the time spent in class and the "flipped" approach in general. Students in the second offering performed worse than traditional sections, but given the small populations considered, the significance of the results should be downplayed. In addition, the difference in exam scores between the traditional sections and the combined "flipped" sections was statistically insignificant.

Generally, the "flipped" classroom approach in this statics course seemed successful. Past students often requested more in-class example problems and the "flipped" approach certainly allowed for more opportunities in class for examples. Students conveyed that they struggled with the underlying theory presented during online lectures, but perhaps no more than if it were presented during class. The material is challenging whether presented online or in class. The results from the final exam suggest that there is little advantage, if any, to a "flipped" classroom. However, based on the subjective perception of the instructor as well as the qualitative responses from students, this approach does have advantages, especially in the engagement of students during problem days. This instructor will continue with this course

structure in statics and apply it in other engineering mechanics courses. With that said, if other instructors prefer a more traditional approach, there seems to be no statistical reason to unwillingly switch to a "flipped" classroom. It is the author's belief that any instructor should be comfortable and confident in the structure of the course in order to successfully deliver the necessary knowledge to students.

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