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Flipped Online Learning with Synchronous Meetings in an Engineering Thermodynamics Course

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Abstract

Thermodynamics class was taught fully online-flipped with regular synchronous online meetings. Students view pre-recorded lectures with embedded problems that they solve before each class meeting. The embedded problems were similar to problems solved in the pre-recorded lecture. The online synchronous meetings were devoted to addressing muddy points and follow-up questions. This format allowed the instructor to reinforce important concepts. Student learning was evaluated by class performance on exam problems used in previous face-to-face semesters. Data showed that student learning was comparable to previous semesters. Student evaluations of the flipped online course were higher than previous online semesters but still below previous face-to-face semesters.

Introduction

Because of covid, many engineering classes have been forced to be online since the middle of spring of 2020 and have struggled to engage students and uphold academic standards [1]. The thermodynamics class was to be offered online during the summer of 2021, and a more effective format for the class was sought. Flipping a thermodynamics class allows more time for discussion and problem solving and most students indicate this builds their confidence in the course [2]. Pre-covid studies show that online courses should include some face-to-face or at least some synchronous meetings to provide in-depth explanations and clarifications of difficult concepts [3]. The thermodynamics courses traditionally use class/lecture time for instruction with problem-based exams and homework used to assess student learning, often using conceptual questions [4]. Some faculty describe implementation of an online thermodynamics course using a flipped class model, and report that student learning is comparable to face-to-face courses [5]. With an online course, it is important to have an organized layout for the course, since students easily get lost and may fall behind [6]. Some faculty report increased student satisfaction with recorded lectures so students can review them [6]. Assessment of student learning in online course is more challenging than face-to-face primarily because some students communicate with others during remote exams and have used online tutoring services during exams [7]. Cheating is more of a problem with online exams compared to face-to-face exams [1]. In some cases, cheating is an act of desperation at the end of the semester after the student has procrastinated and is faced with the reality that they can only pass the class with a near-perfect grade on the final exam. Previously the authors tried a flipped approach to a face-to-face thermodynamics course, yet the results were less than satisfactory primarily because students did not complete the assigned tasks before attending class [8]. The flipped model was tried again in forced online class knowing that students need to complete assigned tasks on time. It is also decided that a flipped online course needed to have a more structured schedule than typical face-to-face offering of the same course.

Course Description

Thermodynamics class was taught online with asynchronous learning content coupled with regular synchronous meetings. The class was completely online and included five main elements: (1) pre-recorded "lecture" sessions, (2) "homework" problems presented in the pre-recorded lecture, (3) muddy point reflections at the end of each pre-recorded lecture, (4) online asynchronous discussion of muddy points with the students, and (5) online exams. Muddy point reflections give students the opportunity to share what they found most difficult or confusing about the lecture, reading, or activity [9], [10]. At the end of every lecture, the same muddy point question was asked and the responses were "graded" to encourage participation:

> "What part of the lecture material do you find the most confusing or most challenging? Please describe at least one and no more than three muddy points."

The purpose of this question is to enhance student reflection on the material and to provide the seed for online class discussion.

The pre-recorded lectures were just like face-to-face lectures without student interaction. They were kept to the allotted time of the typical class meeting, which is 110 minutes for a summer course. In some cases, the lectures were subdivided into parts. The lectures had a balance of theory and applications. The application problems were similar to multi-step homework problems. Students were given problems they were to solve following the pre-recorded lecture. The solutions were graded, just like homework problems. The students were to work these problems out systematically, showing sufficient details so the grader could follow the work. The solutions to the problems were submitted 2 hours before the scheduled online class meeting. The instructor used the 2 hours between the deadline and the beginning of class to organize the muddy point responses. Often student responses were similar, so they were grouped. The exact words used by the students were often used in the discussion to show that the instructor read all of the student feedback and show that the instructor was responding to student feedback. It was hoped that students would reflect more seriously on the lecture material if they knew the instructor responded to their feedback.

It was clear that completing the problems before each class was challenging for many students, especially in the beginning of the semester. Deadlines were flexible in the beginning of the semester to help students adjust to the class, but deadlines became firm as the semester progressed and no late work was accepted. If they could not keep up with the assignments, this would help show some students that they were too busy with other activities and that it would be difficult to succeed in this class. Early in the semester, the instructor individually emailed students to ask them about missing deadlines, and in a few cases, the students did a realistic evaluation of their busy lives and decided to withdraw from the class before the university census date. Within the first week of the semester about 5% of the students dropped instead of the typical ~2% before census date, and this was attributed primarily to students determining they did not have sufficient time to devote to the class.

Before each class meeting day, the students received the pre-recorded lecture slides. The pre-recorded lecture and problems embedded in the lecture acted like homework. The total number of problems were approximately the same as assigned homework problems in previous semesters.

It took students time to adjust to the intent of the last question about the "muddy point". In the beginning, some students did not expect the instructor to read their responses nor address their muddy points. This changed after the first assignment. One thing that helped promote student responses was that the instructor tried to never (1) ignore or (2) criticize a response. This was a little challenging since some students continued to struggle with concepts that had been covered. These questions were addressed concisely, often by pointing to the previous section in the textbook for the student to review. Each response needed to be addressed, but some were more quickly discussed. More time was devoted to those things the students struggled to understand. The instructor did not require a well-phrased statement. The instructor only asked for a general description of the confusion or what the student did not grasp. Below are some examples of student feedback on the first lecture concerning units:

> *The hardest part about this lecture was the constant conversion of variables. It is something that I have always struggled with.*
>
> *Remembering units.*
>
> *I just need to review the conversion factors. I am rusty from physics.*
>
> *Units was very challenging.*

Student Learning and Satisfaction

During the semester, student learning was measured by comparing class performance on a select number of exam problems used in previous semesters. The first problem included liquid water being heated from a thermal reservoir while also being heated by an electrical resistor. The problem asked for the entropy produced in the process. The second problem had an ideal gas undergoing polytropic process, and students were asked to calculate final state temperature and change in gas entropy. The third problem was a steam turbine with students being asked to calculate power produced, entropy production rate and isentropic efficiency. Each exam problem had similar format and wording that was consistent with the lectures and homework problems.

Figure 1 shows each problem scores normalized to a 100-point scale since they may have been worth 30 or 40 points of the exam. The number of students solving each problem was N=58 and N=36 for P1 and P1*, N=52 and N=36 for P2 and P2*, and N=80 and N=34 for P3 and P3*. The mean score is indicated by the solid bar and the additional vertical line indicates the standard deviation added to and subtracted from the mean score. About 70% of the scores fall within the range of the bars. Because of the overlap in the range bars, the scores are considered similar for the problems and it was concluded there is no observed difference in student performance on these problems. It is preferable to use the full exams over numerous semesters to quantify trends in student learning. Reusing full exams is not a reliable metric since students often study past exams, especially if they expect exam problems to be reused.

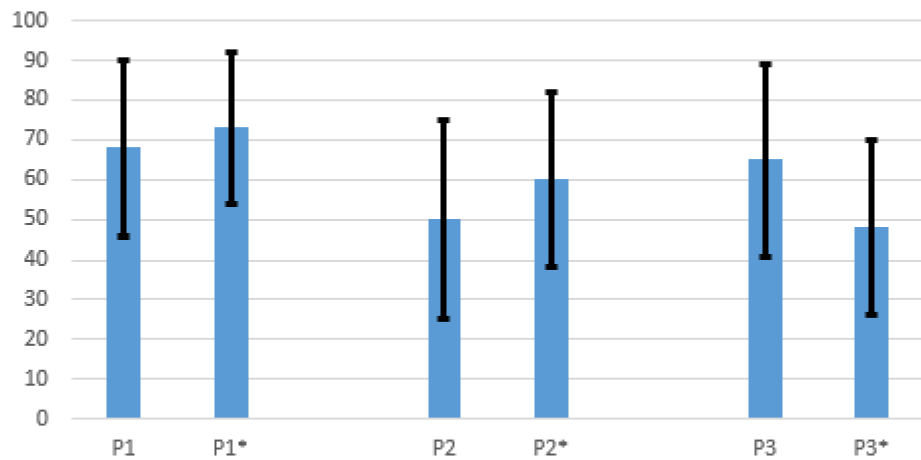

Figure 1. Normalized scores on three problems (P1, P2, P3) with the score on left from a previous semester and on the right from current semester using flipped-online format indicated with asterisk.

Figure 2 shows three semesters of student evaluation of the thermodynamics course. The first semester is face-to-face in the Fall 2019. The second and third are online because of covid with Fall 2020 and Summer 2021. The student evaluation of the online course are below the face-to-face. Yet there is improvement in the second online offering using the flipped online format.

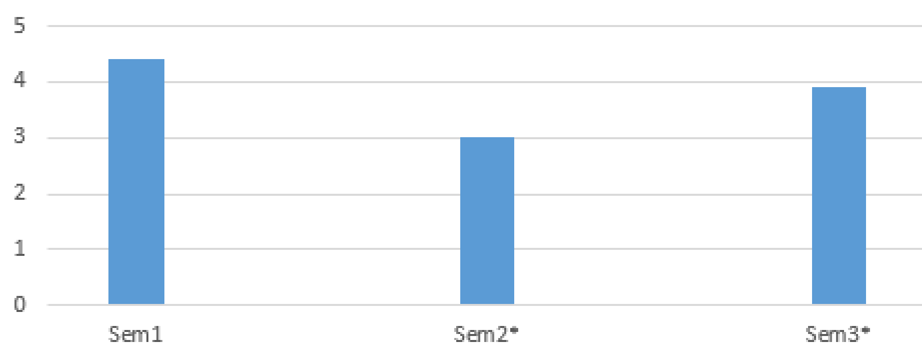

Figure 2. Student evaluation of thermodynamics course for three semesters. The first is not online, but face-to-face. The second and third are online as indicated with asterisk. The Sem3* is the only semester using flipped-online format.

Anonymous student comments were mixed. Some commented that the course was during a condensed summer session and being online was challenging. Some students prefer more traditional lecturing and problem solving instead of question-answer discussion of conceptual issues.

I definitely enjoyed the reverse classroom concept that the professor gave for this summer course. This allowed me to be able to look back at lecture and review material that I found difficult.

It is a hard class taken during the summer and is online which is a recipe for disaster anyway, but I would study the concepts from the lectures and still felt ill prepared for the tests. It was also hard to keep a strong engagement on the long recorded lectures.

Making us watch lecture videos where he skips steps, and has the class session as a question session, I'd prefer him actually going over lecture material.

Summary and Conclusions

A flipped format was used in an online engineering thermodynamics class. The course was forced to be online because of covid. The motivation for flipping was to increase student engagement and reduce procrastination. At the end of each pre-recorded lecture, the students were asked to summarize muddy points. Follow-up synchronous class time was then devoted to the muddy points and conceptual issues. Overall, student learning was found to be similar to previous face-to-face semesters. Student satisfaction was improved over previous online semester but still below previous face-to-face semesters. A continuing challenge is that some students do not enjoy any online engineering course. It is recommended that the flipped format be retained in future online classes while possibly changing what is done during the online synchronous class meetings. Instead of focusing on conceptual issues and student questions, the time can be devoted to solving additional problems selected after review of student muddy point feedback.

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