An Experiment with Flipped Classroom Concept in a Thermodynamics Course

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Abstract

Flipped classroom is an instructional concept that reverses the traditional method of teaching by providing instructional content in advance outside of the classroom and bringing some of the outside activities such as solving problems into the classroom. Flipped classroom concepts was recently experimented in two sections of an introductory undergraduate course in thermodynamics. Students were assigned to read specific sections of the textbook and review previously prepared power point presentation of lectures before attending lecture periods. Electronic respond devices, such as I-Clickers, were used to gage students understanding of assigned reading material by starting class with a quiz. The concepts were explained in detail. When students had difficulties with the specific topics related to quiz questions, a second quiz was given later to see if the students' understanding of the material were improved. A survey was conducted near the end of semester to seek student feedback on their experience with the flipped classroom concept. The paper includes the results of the student survey.

1. Introduction

An introductory course in thermodynamics is required in all undergraduate mechanical engineering (ME) degree programs. Some institutions require a two courses sequence in thermodynamics in their program. For example at the University of Texas at San Antonio (UTSA), the BS degree in ME program requires a two-course sequence in thermodynamics for six (6) semester credit hours (SCH). The first course, ME 3293-Thermodynamics-I, covers the fundamental concepts where students are introduced to such definitions as thermodynamic systems, extensive or intensive properties, forms of energies, work and heat transfer, conservation of mass and energy, and the second law of thermodynamics. Students also learn how to use tables, charts, appropriate equations, and software programs to evaluate thermodynamic properties. Basic power, and refrigeration, cycles are introduced to demonstrate the application of the fundamental concepts. The second course, ME 4293-Thermodynamics II, covers exergy analysis, the analysis of advanced power and refrigeration cycles, thermodynamics relations, ideal gas mixtures properties, psychrometric applications, combustion, and chemical/phase equilibrium.

The introductory course in thermodynamics is one of the challenging courses in the ME undergraduate curriculum. Many of the topics covered in the course are new to students and some students struggle to grasp the fundamental concepts. For these reasons, students' failure rate is typically high in this course. Figure 1 shows the students' passing rates in ME 3293-Thermodynamics-I taught at UTSA between fall semester 1994 and spring semester 2013 [1, 2]. During this period, one or two sections of the course was offered every fall and spring semesters, and one section was offered during most summer sessions. The course was offered 57 times and was taught by ten different instructors during that period. Only grades of C- and better are considered as a passing grade in this course at UTSA. The figure exhibits a wide range of variation in passing rate, even for the same instructor teaching the course in different semesters. The factors influencing the passing rates can be attributed to class size, the quality of students in a given class, grading scale of difficult instructors, and the quality of the teaching. Student passing rates have been as low as 24% for a section taught by one instructor and as high as 92% for another section taught by another instructor. Overall, 52.7% of students who attempted ME 3293 between 1994 and fall semester 2012 passed the course.

The two authors of this paper are labeled as instructors numbers 1 and 2 in Fig. 1, have taught the majority of students who have attempted ME 3293. They have used various teaching concepts and student learning tools to engage students to help them to learn the fundamental thermodynamic concepts [3-13]. These efforts include hands-on laboratory experimentation in thermodynamics and implementation of thermodynamic software for property evaluation. One method not tried yet was the "flipped classroom concept."

1.1 Flipped Classroom

Wikipedia describes Flipped classroom as "an instructional concept that reverses the traditional method of teaching by providing instructional content in advance outside of the classroom and bringing some of the outside activities such as homework into the classroom. In a flipped classroom, students may be required to read the textbook material or watch lectures online before each class period. In turn students spend some of the classroom time to solve example problems, engage in classroom discussion under the guidance of the instructor, or answer quiz questions." The flipped classroom concept has been a hot pedagogical topic in the recent year. Some of recent studies have reported that flipping classroom creates successful learning environment for students [14, 15].

Recently we conducted a surveys an undergraduate heat transfer course to gage students' feelings towards the flipped classroom concept. The flipped classroom concept was described in the survey first. Then they were asked to respond to the two questions listed in Table 1, if the flipped classroom strategy was to be used in one of their engineering courses.

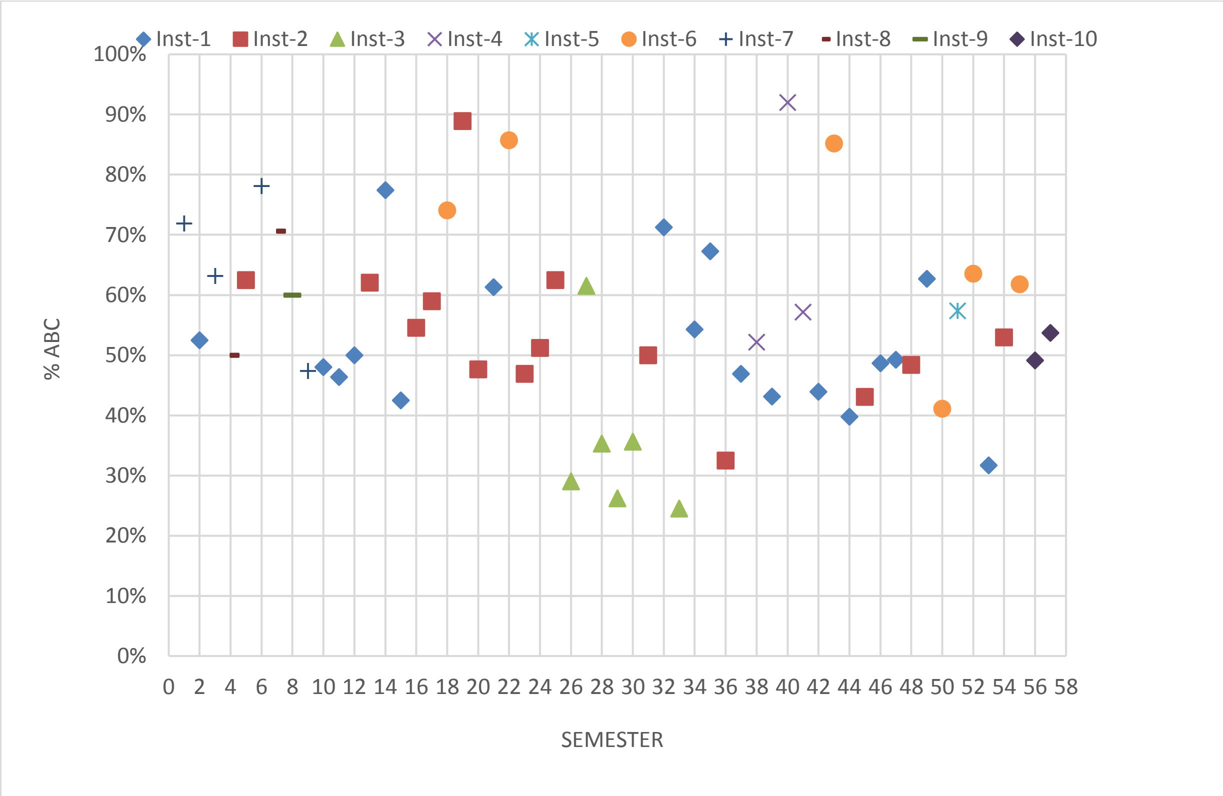

Fig 1. Passing rate in ME 3293-Thermodynamics-I between fall 1994 and spring 2013

Students had the following choices in responding to the questions on the survey: strongly disagree (SD = 1) disagree (D =2), Neutral (N=3), agree (A =4) and strongly agree (SA =5). The results are summarized in Fig 2. The results shows that the majority of the students agreed that flipped classroom strategy is a very good learning concept, with an average agreement level of 3.7. However, when asked if they would read the textbook or review the lecture notes in advance before attending lecture periods, many indicated that they would not, with an average agreement level of 2.9.

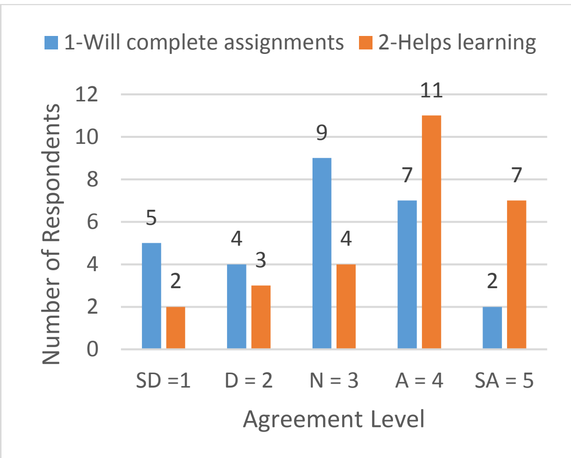

Fig 2. Survey results regarding to the implementation of flipped classroom concept. 1- would you make sure to complete the reading or watching lecture video assigned prior to coming to class?, 2-will flipped classroom concept help the learning process?

2. Flipped Classroom Experiment

The flipped classroom concept was tried in two sections of ME 3293-Thermodynamics-I offered in fall 2017. The same instructor taught both sections. The enrollment included 70 students in the first section and 60 students in the second section. Initially, students were given reading assignment from the course textbook [16] before attending each lecture period. Students were encouraged to use other learning resources available to them. The available resources included the textbook's Student Companion site [17] and the lectures recorded on youtube.com by one of the authors when he taught the course in previous semesters [18]. The textbook companion site provides such learning resources as lecture power point presentations, animation of thermodynamics systems and processes, tutorial for using steam tables for the evaluation of thermodynamics properties, and the Interactive Thermodynamics (IT) software program that can be uses for property evaluation and solving complex problems.

In recent years, Randall Manteufel has been recording lectures and posting them on youtube.com. Students can view lectures online, which have been recorded and made publically available for viewing. This is increasingly common where instructors organize lectures in PlayLists for each class and each semester. The PlayList is often sequentially organized from the beginning of the semester. Lectures are often segmented into shortened video and given labels to help students find information on particular topics. Searching keywords in titles and descriptions help students find information. Students often comment they can replay sections of the lecture, pause and work it out in more detail, especially in areas where they find the material challenging. The last time that ME 3293 lectures were posted on YouTube, was in summer 2016 and students enrolled in ME 3293 during fall 2017 were encouraged to also [19] view the recorded lectures related to the reading assignments.

Electronic respond devices such as I-Clickers are very useful in taking attendance, give short quizzes, or use as a student learning resource tool, especially in classes with large enrollment [3]. In fall 2017, I-Clickers were used in ME 3293 to gage students understanding of assigned reading material and engage them to participate in the classroom activities. During lectures, the instructor asked students questions related to the topics that was being discussed and students registered their responses through I-Clicker devices. The instructor would explained the topics in more detail when students had difficulties with the specific areas of questions asked during the class. A quiz was given later to see if the students' understanding of the materials had improved. For example after students were assigned to read the sections of the textbook describing various types of thermodynamics systems and properties and the materials reviewed in class quickly, the following true/false and multiple choice quiz was given to assess students' understanding of the materials.

Example Quiz:

A. Answer the followings as (A)-True or (B)-False.

1. The volume of a closed system **cannot** change during a process
2. When a thermodynamics system undergoes a process between two specified states, the

changes in thermodynamic properties between the end states depends on the path of the process.

B. For the followings, identify each item as: (A)-Extensive property, (B)-Intensive property, or (C)-Not a property.
3. Volume, V
4. Heat transfer, Q
5. Temperature, T
6. Work, W
7. Density, ρ

C. For the followings, identify each item as: (A)-Open System, (B)-Closed System, or (C)-Isolated System
8. A tank being filled with compressed air (boundary is at inner surface of tank)
9. Air expanding in a piston and cylinder arrangement while it is being heated
10. An electrical motor providing power to an air-compressor
11. Hot water in a well-insulated rigid container

Students were asked to use their I-Clicker devices to submit their answers. As soon as students completed their responses during the allotted time, the results of responses to each question were displayed on the classroom screen. Figure 3 shows the percentage of correct answers to questions 1 and 9. The percentages of correct answers to the remaining questions in the original quiz are presented in Table 1. The results shows that the majority of students had difficulties to answer some of the questions. Right after the quiz, the topics related to the questions were reviewed again, especially in the areas that most students did not answer the questions correctly. The same quiz was given during the next class period and the percentage of correct answers for each questions are listed in Table 1. The table displays a vast improvement in the percentage of correct answers to each question.

Shortly after the start of semester, it became clear that many students were not either completing the reading assignments or did not understand the materials they read. Therefore, the reading assignments were reviewed during the lecture periods, before students were given a diagnostic quiz on the assigned reading topics.

Approximately one-third into the semester, some students suggested that the power point presentation of lectures be made available to students in advance. Previously the power point presentation of each chapter was posted on UTSA Blackboard Lean course webpage, as soon as the lectures related to each chapter were completed. Starting with the second third of the semester period, the power point presentations of lectures for each chapter were posted on blackboard in advance and students were asked to review them in additions to the reading assignments.

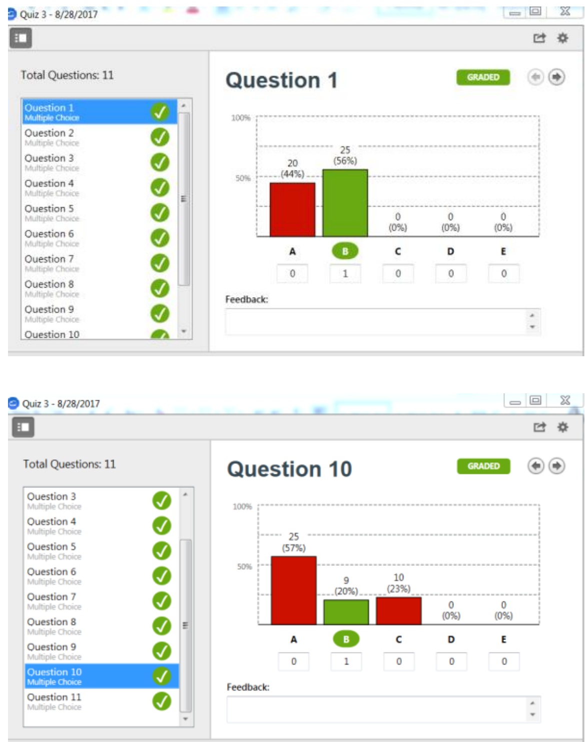

Fig3. Percentage of correct answers (green color) to questions 1 and 10 in the original quiz

Table 1. Comparison of results between the original and repeated quizzes - percentages of correct answers

Question	Original Quiz	Repeated Quiz
1	56%	83%
2	42%	80%
3	70%	91%
4	28%	83%
5	63%	89%
6	50%	91%
7	57%	87%
8	52%	91%
9	73%	89%
10	9%	74%
11	45%	87%

The power point presentations of lectures included some of the slides provided by the publisher, and additional slides prepared by the instructor. The power point presentations included, basic definition of thermodynamics systems, some of diagrams from the textbook, results of equations derived during the lectures, and solutions to the example problems solved during the lectures. The power point presentation did not include the detailed steps used in deriving formulas during the lectures. The power point presentations posted in advance include the problem statements for the examples used during the lectures, but did not include the solution to the example problems. The power point presentations were updated with the solutions after students helped solving the example problems during the lecture. The power point presentations of lectures were updated with the solution of example problems and posted on blackboard.

3. Students Feedback

A survey was conducted near the end of semester to seek student feedback on their experience with the flipped classroom concept. A total of 99 students enrolled in two sections of the course participated in the survey. In the first part of the survey, students were asked to identify the percentages of time that they had completed the reading assignments or reviewed the power point presentations of lectures prior to the time that the material were discussed in class. Students were given the following choices as: 80-100%, 60-79%, 40-59%, 20-39%, and less than 20% of the time. The results of the answers are presented in Fig. 4. As shown in the figure, less than 25% of students completed more than 60 % of reading assignments and less than 55% of students reviewed more than 40% of the power point presentations posted on blackboard before the topics were presented and discussed in class.

Through a number of statements, the survey questionnaire also sought students opinion regarding the effectiveness of the reading assignments, power point presentations, and the use of I-Clickers as a tool for learning process. Students were asked to use the following scales to rank their agreements with each statement in the survey: (5) = Strongly agree, (4) = Agree, (3) = Neutral, (2) Disagree, and (1) Strongly disagree. The results of student rankings for each statement are summarized in Table 2 Some of the survey questions had been asked in a survey questionnaire conducted earlier in a heat transfer course in fall 2016 [3]. For comparison, the results of the earlier survey are also presented in Table 2

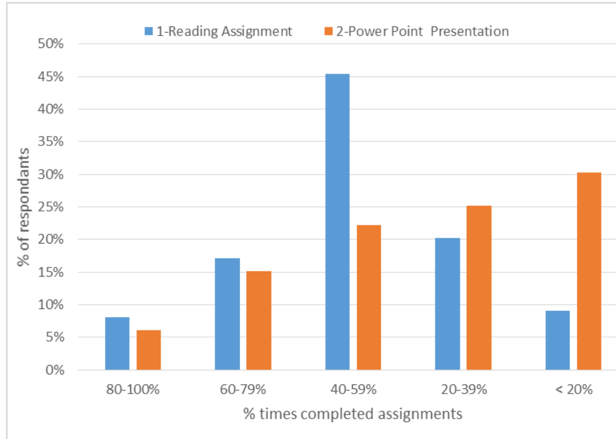

Fig. 4. Percentage of times the reading assignments completed and power point presentations reviewed: 1-Reading assignments, 2-powerpoint presentations

The results in Table 2 indicate that more students agreed that the reading assignments helped them more to understand the course material than reviewing the power point presentations posted in advance. It should be noted that more students also completed the reading assignments than reviewing the power point presentation of lectures. The majority of students had the opinion that results of I-Clicker quizzes should not be used as a part of the semester grade.

Almost in all areas, students participating in the fall 2016 survey had a more positive view of using the I-Clickers than those participated in the fall 2016 The following factors might have contributed to the differences in students' point of view. For the first time in fall 2017, students had to register their electronic response devices through I-Clicker Cloud (www.Iclicker.com), than the "blackboard learn" as it was done in the past. This created some confusion and delays at the beginning of the semester. The heat transfer course in 2016 had much lower enrollment that the sections of thermodynamics course offered in fall 2017. In smaller class setting, more students have the opportunity of participating in the class discussions than those in the courses with larger enrollments. Students in the heat transfer course were more advanced in their academic educations than those who were in the introductory thermodynamic courses.

Students in heat transfer had already completed courses in Thermodynamics-I and Fluid Mechanics, and some had completed Thermodynamics-II. Many of students in heat transfer course had already taken a course from the instructor, while none in ME 3293 had taken a course from the instructor before. Student academic performance in the course may also influence their responses to the survey questions. The heat transfer course had a much higher passing rate than each section of the thermodynamics course.

Table 2. Summary of student responses to the level of their agreements with the statements in the survey questionnaire: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree

	Statement	Fall 2017 Survey							2016 Survey	
		5	4	3	2	1	N	Ave	N	Ave
1	Reading assignments in advanced helped my understanding of course material	15	34	30	16	4	99	3.4	-	--
2	Review of power point presentations in advance helped my understanding of course material	7	19	36	28	9	99	2.9	-	-
3	I-Clicker is a good tool to assess student knowledge	21	31	22	14	11	99	3.4	27	3.8
4	Use of I-Clickers helped me be alert in the class	19	35	19	16	10	99	3.4	27	4.1
5	Use of I-Clickers helped me to participate in the class activities	23	36	21	14	5	99	3.6	27	4.1
6	Use of I-Clickers helped me to find out immediately if my answers were correct	45	30	12	5	6	98	4.1	27	4.0
7	Use of I-Clickers in this course helped me to learn new concepts	9	18	35	21	16	99	2.8	27	3.6
8	Use of I-Clickers in this course helped me to attend class on regular basis	25	23	24	15	12	99	3.3	27	3.6
9	Results of I-Clicker quizzes should be used as a part of semester grade	9	15	27	23	25	99	2.6	-	-
10	Continue using I-Clicker in the courses as a part of the teaching/ learning process without using the results for contribution towards the final grade	21	31	22	14	11	99	3.4	27	3.7
11	Continue using I-Clicker in the courses for short quizzes	19	35	19	16	10	99	3.4	27	3.7

4. Summary

The Flipped classroom concept was tried in two sections of an introductory thermodynamics course offered in fall 2017. The experiment was not as successful as it was originally hoped. The success of the concept depends on the students' willingness to complete the assigned task before attending class. In our experiment, a large number of students did not complete the reading assignments nor viewed the power point presentation of lectures in advance. Therefore, a good percentage of time was used by the instructor to review the course materials, before students were ready for solving problems in class.

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