A New Approach to Thermodynamics

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Abstract

After teaching a class several times, changing the presentation is essential to keep the material interesting for me. Having taught Thermodynamics numerous times and having three sections scheduled for Fall semester 1998 prompted me to take the collaborative approach described here.

Many discussions of collaborative learning focus on the general techniques to be used. These ideas are all helpful but the application to a particular course is often unclear. Thus, this paper includes the description of a collaborative presentation of several typical Thermodynamics topics. Being aware of the classroom atmosphere is essential in making collaborative learning work. As such, the presentation of the topics includes alterations made to accommodate the personalities of each section.

In what has become the "typical" collaborative learning classroom setup, the tables are in groups, not rows. As such, short group activities are enhanced. Some days, students spend more class time teaching each other than I do lecturing. Other days, I do most of the talking and punctuate the topics with short problems for the groups.

The effects of the classroom arrangement and methods used to present materials are determined using student evaluations throughout the semester. In addition, student performance on a common, course-wide final examination is examined.

Introduction

The course described in this paper is Engineering Thermodynamics, a semester-long course that introduces engineering students to thermodynamics. Most students in the course were first-semester juniors. During Fall semester 1998, I taught three sections (approximately twenty students per section) of this course using a collaborative approach. This paper summarizes some of the teaching techniques used by providing descriptions of the presentation of several typical thermodynamics lectures. Observations resulting from the semester and an assessment of the effectiveness of the collaborative approach are provided.

Typical "Lectures"
I. Definitions

In most courses, students typically learn the language particular to the subject matter early in the semester. The amount of language necessary to begin having a discussion of a thermodynamics problems can be overwhelming. In addition, using a traditional lecture approach to provide the definitions for the students often leads to boredom for the instructor and the students.

I wanted to accomplish two things in this class period: emphasize that I expected the students to do the assigned readings and have the students gain an understanding of the terminology. I accomplished the first objective by giving them a handout listing the words I wanted them to understand. First, with their books closed, I asked them to define the words as they recalled them from the previous night's reading. Typical words were specific volume, pressure, adiabatic, temperature, and the like. After five minutes, I assigned each student one word from the handout. The students were instructed to use their book and other thermodynamics books I brought in to find a definition for their word. The definition was to be based on their understanding, not a rote repetition of the definition from the text. Each student was to then explain the meaning of their word to others at their table and answer questions that arose. Finally, each student defined their word for the entire class and answered questions.

In the past when I have defined the words on the board, it often took more than one lecture. Using the collaborative approach, I was pleasantly surprised to cover all of the definitions in less than one class period. During the semester, I used any time left in the class period for the students to start the homework. This allowed me to answer questions and see what aspects of the material gave the most trouble when put into practice.

II. T ds equation development

The T ds equations are very important in illustrating the determination of entropy for a variety of substances. I have found that students often ignore the derivations of the T ds equations in the text and deriving the equations in class can lead to boredom. As such, I decided to let the students derive the equations in groups. I gave them a leading handout and they were to fill in the blanks. The text of the handout follows.

T ds EQUATIONS:

ALL equations that you write should be on a differential basis (e.g., the heat transfer is expressed as δq and Δe is written as de.)

1 - Write the Conservation of Energy equation for a closed system.
2 - Divide the above equation by the system mass.
3 - If changes in kinetic and potential energy are negligible, what is the simplified expression for de?
4 - If the process is internally reversible, write the expression for the heat transfer as given by the definition of entropy.
5 - If the only work involved is boundary work, what is the expression for δw?
6 - Put the expressions in 3, 4, and 5 into the equation in 2:
7 - Solve 6 for T ds:

This is the first of the T ds equations. Since all terms in this equation are properties, this relationship holds for ALL processes (recall a similar development for specific heats).
8 - What is the mathematical definition of enthalpy?
9 - Solve 8 for u:
10 - Write the differential expression for u based on the expression in 9.
11 - Substitute 10 into 7 and simplify.

This is the second Tds equation. Again, this applies for all processes.

While the students were working on this handout, I answered any questions that the small groups had. After the groups developed the expressions, we went over the final T ds expressions as a class. The handout then became their reference for future development of expressions for entropy change for ideal gases and incompressible substances.

III. Cycles

By the time cycles are covered, all of the fundamentals (conservation of mass and energy, the stated postulate, and the Second Law) have been conveyed. Thus, the only new idea in cycle analysis is understanding how the processes fit together.

Each time I introduced a new cycle, I would discuss the basics of its operation and the "real world" applications of the cycle. Students who had experience with particular cycles would share their knowledge and we discussed the complexities that could be included in the cycle analysis. Typically, the analysis would seem overwhelming and students gained an appreciation of the simplifications I offered for analysis purposes. Students then analyzed each process in groups, applying the conservation equations. Finally, each group explained the process they analyzed to the rest of the class and we talked about tools we had already learned that would provide property information.

Student Evaluations

In all the courses I teach, I typically have students do an informal course evaluation mid-semester. I asked students to do an evaluation of the collaborative Thermodynamics course about six weeks into the semester. Students were given several questions to answer and no suggested responses were provided. The questions students were asked and a summary of their responses are provided in Table 1. Approximately 55 students filled out an evaluation. Numbers in parentheses indicate the number of students who indicated the stated response.

I reduced the responses to the form shown in Table 1. Then I sent the table and my feedback to all students via email. As seen in Table 1, the responses to Item #1 strongly indicate, in various ways, a preference for group work. My feedback consisted of responses to the two items that more than two students mentioned for Item #3. I told the students in my response that the items which were mentioned by only one or two students should be addressed with me individually via email or in person. Aspects of the course that were enhancing learning as indicated in Item #1 were not changed.

Conclusions

During the course of the semester, I found that one section tended to need more attention and repetition than the others. This section generally had more questions, was slower picking up new material, and did not perform as well as the other sections on exams and quizzes. I addressed this by trying to anticipate the more difficult points and then planning an opportunity for a group activity associated with it. During the group activity I could work with students in small groups and aid those who were having difficulties.

Overall, implementing collaborative learning in the introductory thermodynamics course was effective. Student evaluations were positive. When asked on the course evaluation if the classroom atmosphere promoted learning, nearly 70% of the students indicated that it had. Only 10% of the students thought that the classroom atmosphere hadn't enhanced their learning. The remaining 20% did not respond to the question.

The section with the highest average on the final exam was collaboratively taught. This section also indicated the most positive response to the classroom atmosphere on the course evaluation. In all, seven sections of the course were taught during the semester discussed herein. A course-wide final exam was given. Student performance on the final was very similar for those students in traditionally and collaboratively taught sections.

Item #1. Please list those aspects of this course that you feel are enhancing your learning experience.	
Group work (23) Working problems in class (17) Going over homework problems at start of class (15) Interactive lectures (9) Distribution of HW solutions (7) Daily HW (6) Lectures (2)	Preparation for career (2) Quizzes and/or tests (2) Handouts (2) Problem solving method (1) Textbook (1) Deriving formulas (1)
Item #2. Please list those aspects of this course that you feel are not enhancing your learning experience.	
Homework, quizzes (5) Lack of numerical answers to HW ahead of time (4) Speed of material coverage (4) Vague goals/topics (3) Complaining/noise by students (3) Group work (3) Group seating (3) Lack of practical applications of material (2)	Test did not go along with HW (2) Textbook (2) Lack of preparation for the next HW (1) Difficulty in understanding prob solving method (1) Distraction due to view of water (1) Non-interactive parts (1) Spending too much time on one problem (1)
Item #3. For those topics listed in Item #2, provide suggestions on how they could be altered to enhance your learning experience.	
More problems in class (17) Provide homework answers ahead of time (3) New textbook/ good class notes (2) Cover numerical work on homework problems (2) Questions representative of homework for exams (2) Teach this like an engineering class (2) More office hours (1) Focus on next homework (1) More lecturing (1) More group problems (1) Students work at board in groups (1)	Specify exam contents (1) "Normal" seating (1) Lower room temperature (1) Explain how tables are used (1) Highlight goals at start each lecture (1) Summary sheet of variables (1) Real world examples (1) Slower coverage (1) Provide challenges for advanced students (1) Cover problems more quickly (1) Review before exam (1)

Table 1: Mid-semester evaluation responses

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