Effectiveness of Flipping an Undergraduate Thermodynamics Course

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Abstract

The undergraduate Thermodynamics I course at North Carolina State University has been taught in the flipped format for the past two years. The course is required for several engineering disciplines and is taken by sophomores, juniors, and seniors. Approximately 1000 students have been taught Thermodynamics with the flipped method. The term flipping refers to the change made to the delivery of the content material. The concepts delivered in a traditional lecture are instead provided through online content which allows face-to-face class time to be used on applying the concepts to problem solving. The author has used results from two semesters to assess the effectiveness of flipping the course. Studying the student responses shows that results are mixed but show improvement in some areas.

Keywords

Flipped classroom, effectiveness, undergraduate, thermodynamics

Introduction

Thermodynamics I is an introductory course in the thermal and fluid sciences. It is required for several engineering disciplines at North Carolina State University and is taken by sophomores, juniors, and seniors. The most important objective of the course is analysis of systems using the first and second laws of thermodynamics. Numerical problems and conceptual questions are used to test the students.

Historically, thermodynamics has been a challenging course for students and research is ongoing in the field as to the best educational approach. M.I. Cotignola, et al.[1] considered the influence of caloric theory on current teaching methods and misunderstandings about internal energy and heat. M. Rosen[2] and J. Wang[3] discussed possible changes to teaching exergy and the second law, respectively. Studies have also been done on the effect of using alternative teaching approaches such as active learning and computer-based learning for thermodynamics[4,5].

Since the fall semester of 2013, the undergraduate Thermodynamics I course at NCSU has been offered as a flipped class. Flipping a class gives students more active learning opportunities during class time by changing the delivery of content to online access[6,7]. For this course, video lectures are provided online that cover concepts and example problems. These videos are of the author explaining class notes and solutions, although a recent study by M.J. Jenson, et al.[8] showed that having the instructor featured in the video as opposed to another class's instructor had a negligible effect on student performance. Students are expected to have viewed assigned videos before class so that they can apply the concepts to a problem set. During class, students work in groups in a fixed-seat classroom to solve problems and are encouraged to discuss the concepts involved.

Modifications to Content Delivery

Each semester that the author has taught with the flipped format, modifications have been made to improve the experience and respond to student feedback. Initially, problems were assigned for each class period and groups of three could work at their own pace. A graduate teaching assistant as well as the author were available during each class to assist students. At various points during the class period the author would discuss the problems' solutions and the concepts demonstrated with the class. The solutions would also be posted online after the class for additional study. Student feedback indicated that they disliked self-pacing and equated it to independent study.

To address this criticism, more examples were provided online via video and a personal response system was implemented in class (during what is referred to as Semester 1 for the purposes of this paper). Response systems allow for immediate feedback as to how well a concept is understood by students, but study results are mixed on the improvement to long-term retention of information with these systems[9-12]. The first system used was Top Hat which allowed students to use any device with wi-fi access to log into the course site and submit answers to the problems worked in class when a solution was reached. The author could see the number of online responses and gauge when most of the class had submitted an answer. Then, submissions were closed and shown to the class. The instant feedback meant that the author could spend more time discussing solutions when a significant percentage of the students got the wrong answer and tailor the discussion to address the reasons for the wrong answers. The response system was also used at the beginning of each class for a concept quiz that tested if students had watched the assigned video lecture.

During the next semester (referred to as Semester 2), Top Hat was replaced with clickers from TurningPoint, a technology currently supported by the university. Powerpoint slides displayed each problem in class with multiple choice answers and students submitted answers with clickers or a wi-fi device. This technology did not allow students to work at their own pace since there was only one clicker question per slide. However, the system still allowed the author to know when most students had submitted a response and to show the results to the class. By dictating the pace of the whole class, the author could better encourage discussion by tasking one member per group to explain a problem's solution to his or her group after the solution had been revealed. Having to explain one's work helps students develop communication skills necessary for being a successful engineer.

Students' Performance and Feedback

Student feedback has been gathered to assess how online material is used and the effectiveness of the group work in the class. Additionally, students in two semesters have been asked identical questions on final exams. The course material is delivered in the order presented in the first eight chapters of *Thermodynamics* by Cengel and Boles[13]. The first two chapters explain properties, definitions and the first law. The next chapter explains phase changes and teaches the use of the property tables. These topics are reinforced and applied to closed systems and control volumes in Chapters 4 and 5. Chapters 6, 7, and 8 discuss the second law and the concepts of entropy and exergy.

In Semesters 1 and 2, students were given a final exam that included short answer questions and true/false statements on thermodynamic terms, phase changes, and the first and second laws. Table 1 shows the results of questions about terms and definitions. These questions asked students to identify what a property is and understand the definitions of a heat engine and an adiabatic process. Students in Semester 2 did slightly worse on these problems except for the understanding of heat engines.

Table 1. Percentage of Correct Answers to Questions on Terms and Definitions

	Semester 1 161 Students	Semester 2 122 Students	Percentage Change
Properties	90.4%	86.6%	-3.8
Heat engine	78.4%	79.2%	0.8
Adiabatic process	84.8%	80.8%	-4.0

Four topics were covered with questions about phase changes. Students needed to understand the definition of a particular phase, determine the phase and property from a property table, and calculate the quality. Table 2 shows that student performance improved in all four areas by 0.4% to 7.9%.

Table 2. Percentage of Correct Answers to Questions on Phase Changes

	Semester 1 161 Students	Semester 2 122 Students	Percentage Change
Definition of phase	85.9%	88.7%	2.8
Determining phase	83.6%	84.3%	0.7
Determining property	77.2%	77.6%	0.4
Calculation of quality	27.2%	35.1%	7.9

Multiple questions were asked regarding the first and second laws of thermodynamics. Students needed to analyze a cycle, a closed system, a control volume, and then specifically a heat exchanger. These questions asked students to give equations for the work and heat or explain the result of a process. While students improved in two areas of the first law in Semester 2 (see Table 3), they improved in all areas of the second law (see Table 4).

Table 3. Percentage of Correct Answers to Questions on First Law

	Semester 1 161 Students	Semester 2 122 Students	Percentage Change
Cycle	46.6%	55.1%	8.5
Closed system	65.7%	53.8%	-11.9
Control volume	34.9%	32.1%	-2.8
Heat exchanger	89.7%	91.3%	1.6

Table 4. Percentage of Correct Answers to Questions on Second Law

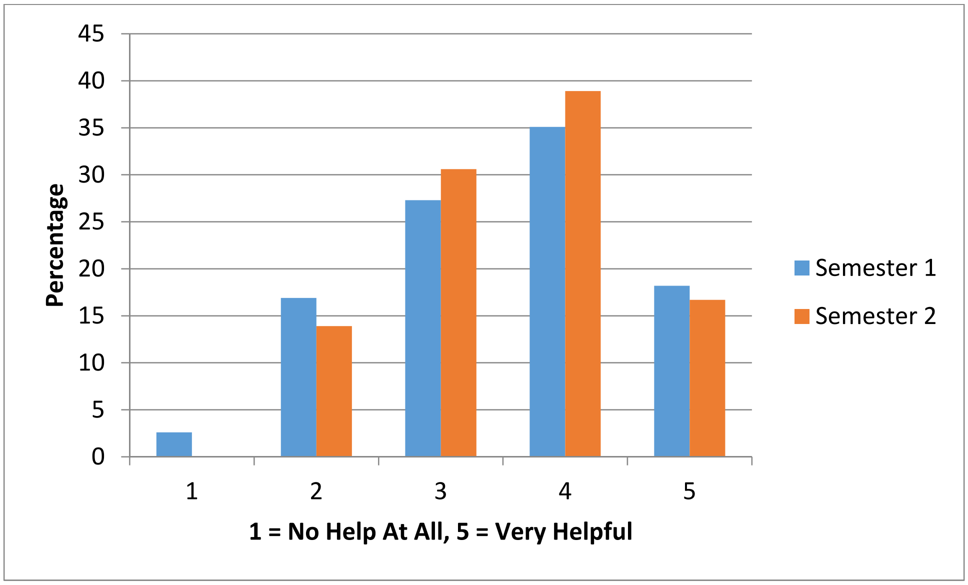
	Semester 1 161 Students	Semester 2 122 Students	Percentage Change
Second law definition	96.0%	96.7%	0.7
Isentropic turbine	80.5%	81.1%	0.6
Carnot heat engine	75.9%	89.4%	13.5

Student resistance to the flipped format has existed since its implementation. During Semesters 1 and 2, students were asked for their feedback in an anonymous and voluntary survey. Table 5 shows the number of respondents and the results of these surveys. Students reported making more use of the online video lectures in Semester 2 and were more positive towards clickers in Semester 2 as opposed to Top Hat in Semester 1. Table 6 shows the results when students were asked how helpful they found it to be working in teams. In both semesters, students generally found the practice to be helpful, but Semester 2 students had a slightly higher opinion. It is unclear if the different number of respondents in each semester accounts for the different results.

Table 5. Student feedback from anonymous surveys

	Semester 1 77 Students Responding		Semester 2 36 Students Responding	
	Yes	No	**Yes**	No
Have you watched any of the video lectures this semester more than once?	**55.8%**	44.2%	**72.2%**	27.8%
Do you like using Top Hat/clickers in class as a real-time response system?	**62.3%**	37.7%	**86.1%**	13.9%

Table 6. Responses to "How helpful have you found it to solve class problems in teams?"



Conclusions

The paper shows the results from two semesters of flipping an undergraduate Thermodynamics course. There were some modifications of the course from Semester 1 and Semester 2 and results culminated from final exams are mixed, but in most areas there was improvement in student performance. Feedback from students was also taken from anonymous surveys given during each semester. The students in Semester 2 were more likely to watch the online videos more than once and were more positive about their in-class response system. The flipped format is still being implemented by the author, and data will continue to be gathered to assess the teaching method.

References

1 Cotignola, Maria I., Clelia Bordogna, Graciela Punte, and Osvaldo M. Cappannini, "Difficulties in Learning Thermodynamic Concepts: Are They Linked to the Historical Development of this Field?", Science & Education 11, 2002, 279-291.

2 Rosen, Marc A., "Thermodynamics Education: Is Present Coverage of Exergy Sufficent and Appropriate?", Exergy, An International Journal 2, 2002, 207-210.

3 Wang, Jitao, "Modern Thermodynamics – New Concepts Based on the Second Law of Thermodynamics", Progress in Natural Science 19, 2009, 125-135.

4 Mulop, Normah, Khairiyah Mohd. Yusof, Zaidatun Tasir, "A Review on Enhancing the Teaching and Learning of Thermodynamics", Procedia-Social and Behavioral Sciences 56, 2012, 703-712.

5 Hassan, Onn and Ramli Mat, "A Comparative Study of Two Different Approaches in Teaching Thermodynamics", Proceedings of the 2005 Regional Conference on Engineering Education, 2005.

6 Zappe, Sarah Elizabeth, Robert M. Leicht, John I. Messner, and Hyeon Woo Lee, "'Flipping' the Classroom to Explore Active Learning in a Large Undergraduate Course", American Society for Engineering Education, 2009.

7 He, Yi, Sandra Swenson, and Nathan Lents, "Online Video Tutorials Increase Learning of Difficult Concepts in an Undergraduate Analytical Chemistry Course", Journal of Chemical Education 89, 2012, 1128-1132.
8 Jensen, Matthew James, Anna KT Howard, and Sherry Jensen, "Flipped Classes: Do Instructors Need to Reinvent the Wheel When It Comes To Course Content?", 122nd ASEE Annual Conference & Exposition, 2015.
9 Lantz, Michael E., "The Use of 'Clickers' in the Classroom: Teaching Innovation or Merely an Amusing Novelty?", Computers in Human Behavior 26, 2010, 556-561.
10 DeBourgh, Gregory A., "Use of Classroom 'Clickers' to Promote Acquisition of Advanced Reasoning Skills", Nurse Education in Practice 8, 2008, 76-87.
11 Dill, Emily, "Do Clickers Improve Library Instruction? Lock in Your Answers Now", The Journal of Academic Librarianship 34, 2008, 527-529.
12 Mayer, Richard E., Andrew Stull, Krista DeLeeuw, Kevin Almeroth, Bruce Bimber, Dorothy Chun, Monica Bulger, Julie Campbell, Allan Knight, Hangjin Zhang, "Clickers in College Classrooms: Fostering Learning with Questioning Methods in Large Lecture Classes", Contemporary Educational Psychology 34, 2009, 51-57.
13 Cengel, Yunus and Michael Boles, Thermodynamics: An Engineering Approach, McGraw Hill, New York, 2015, pg.

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