Predicting Student Performance in Thermodynamics

Nancy J. Moore
North Carolina State University

Abstract

At North Carolina State University, Thermodynamics I is a required course for students in Mechanical and Aerospace Engineering who usually take the class as sophomores. About half of the students enrolled in the class come from other engineering disciplines. When studying Thermodynamics I, students are only successful if topics are mastered sequentially. The first test covers property tables, diagrams and properties. The second test is on first law analysis for closed and open systems. The third test covers basic cycles and the second law. Students that struggle at the beginning of the course often have difficulty catching up on the material. The current study analyzes the test performance from previous semesters to determine how well each test grade predicts if the student will pass the course. Students were offered an opportunity for extra study and data shows that this early intervention by the professor after the first test improved later test grades.

Keywords

Thermodynamics, undergraduate education

Introduction

Thermodynamics I is an undergraduate course in the Mechanical and Aerospace Engineering (MAE) department at North Carolina State University. Within the undergraduate curriculum of the department, students are expected to take the class as sophomores. About half of the enrolled students come from other engineering disciplines, and these students are typically juniors and seniors.

The sequential order of topics in thermodynamics[1,2] means that students can only achieve success in one topic if they have mastered the previous topics. Numerous studies have analyzed the usefulness of office hours[3-4] and study questions[5]. Thus, for the current semester, extra practice problems have been provided prior to the second and third tests to determine if student test performance is improved. The current study analyzes students' test performance for several semesters to determine a baseline by which improvement for the current semester can be measured.

Grade Distribution

Three tests are given during each semester, and every student is required to take the final exam which is cumulative. The first chapters focus on defining systems, property tables[6], and diagrams so a good performance on the first test means that a student understands phases, units, and processes. The second test focuses on the first law for closed systems and control volumes which

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cannot be analyzed without accurate properties and diagrams. The last part of the course on the second law teaches system performance and optimization by introducing entropy.

Table 1 shows the number of students that completed the course for each previous semester, *A* through *D*, and the number of students in the current semester *X*. Four previous semesters were studied to determine the typical performance of students on the three tests and final exam to create a baseline for comparison with the current study. These four examinations account for 75% of a student's final average and so are an accurate reflection of a student's level of understanding of the course material. The MAE department requires that its students earn a C or better to earn credit for the course, so the grade to pass for the purpose of this paper is a grade of at least 69.5%.

Table 1. Number of students in study.

Semester	*A*	*B*	*C*	*D*	*X*
Number of Students	258	236	227	219	180

Figures 1-4 show the grade distribution for semesters *A* through *D* with each figure displaying data from a different test. Because the number of students in each semester varies, these histograms are presented with the percentage frequency. While the tests given cover the same material each semester, the actual test problems change so it is not possible to make a direct comparison.

Some tests show normal distributions like Test 1 and Test 3 for Semester *B* (see Figures 1 and 3, respectively). Multimodality can be seen for most of the tests and is especially pronounced in Figure 4 that presents the final exam grades. These modes suggest that as the course progresses a substantial number of students have fallen behind and done poorly on the test.

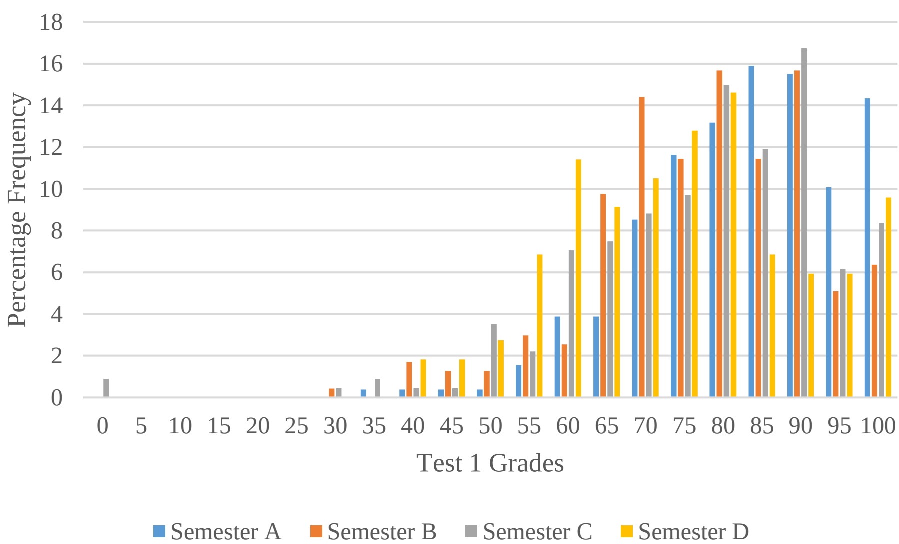

Figure 1. Grade Distributions for Test 1 during Semesters A-D.

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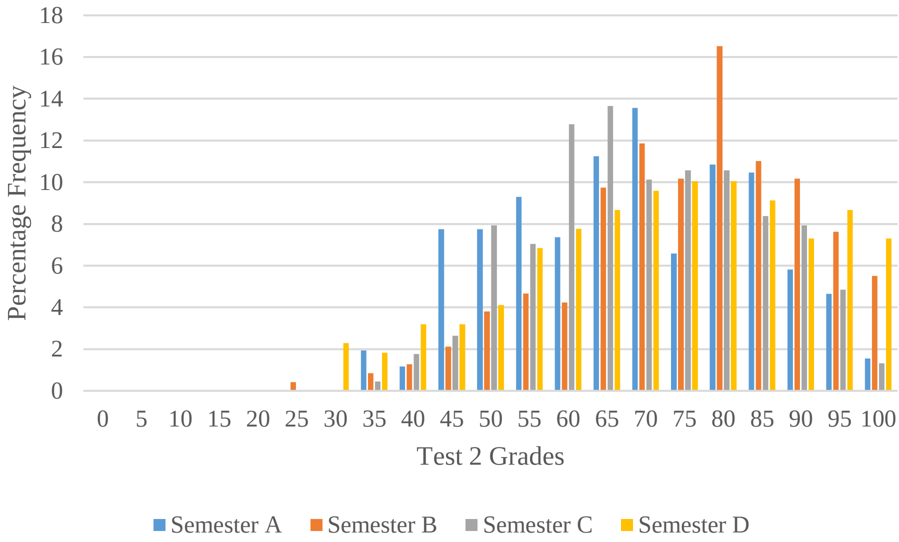

Figure 2. Grade Distributions for Test 2 during Semester A-D.

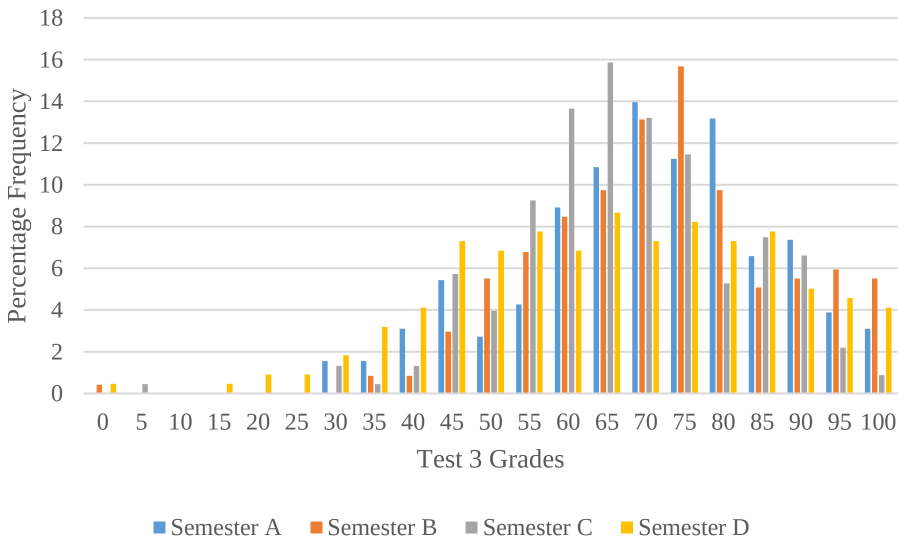

Figure 3. Grade Distributions for Test 3 during Semester A-D.

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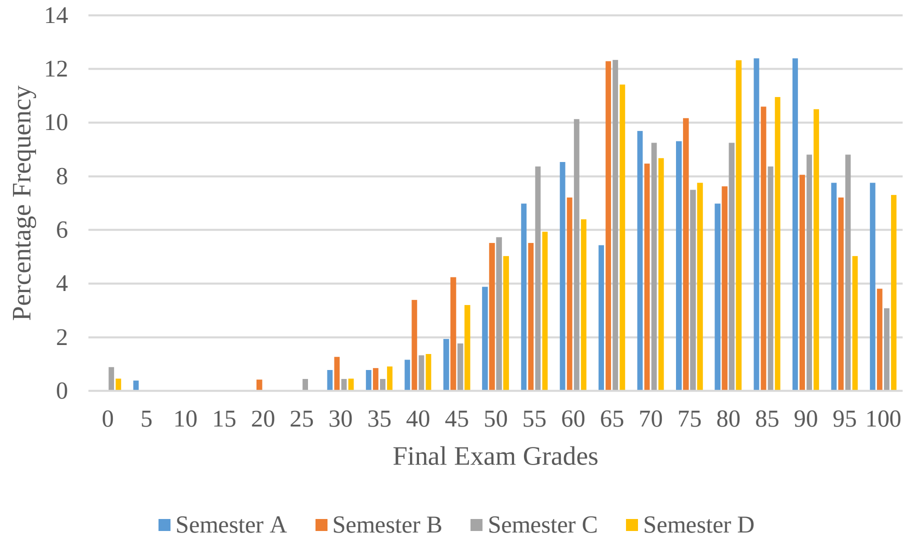

Figure 4. Grade Distributions for the Final Exam during Semester A-D.

Passing the Course

Further analysis of the test grades was performed to determine how well each test grade predicts if the student will pass the course with a C. For each test in semesters *A - D*, the percent of students who scored at or above 69.5% was calculated. Figure 5 shows the results for Tests 1 through 3 and the final exam with solid columns. The largest drop in percentages is between the first and second tests for most semesters. There is a slight drop between the second and third tests and an increase in percentages for the cumulative final exam. For example, during semester *C*, the percentage who passed each test was 70%, 46%, 37%, and 51%, respectively. The black bars indicate the average percentage for each test across all four semesters.

To better analyze student performance throughout the course, the passing rate for multiple tests was determined. The patterned columns in Figure 5 show these results. On average, 41% of students passed both the first and second test and 27% passed the first three tests. 29% of students who passed Test 1 did not pass Test 2. 14% of those that passed Tests 1 and 2 did not pass Test 3. The percentage who passed all three tests and the final exam on average was 23%, so only 4% passed all three tests but not the final exam.

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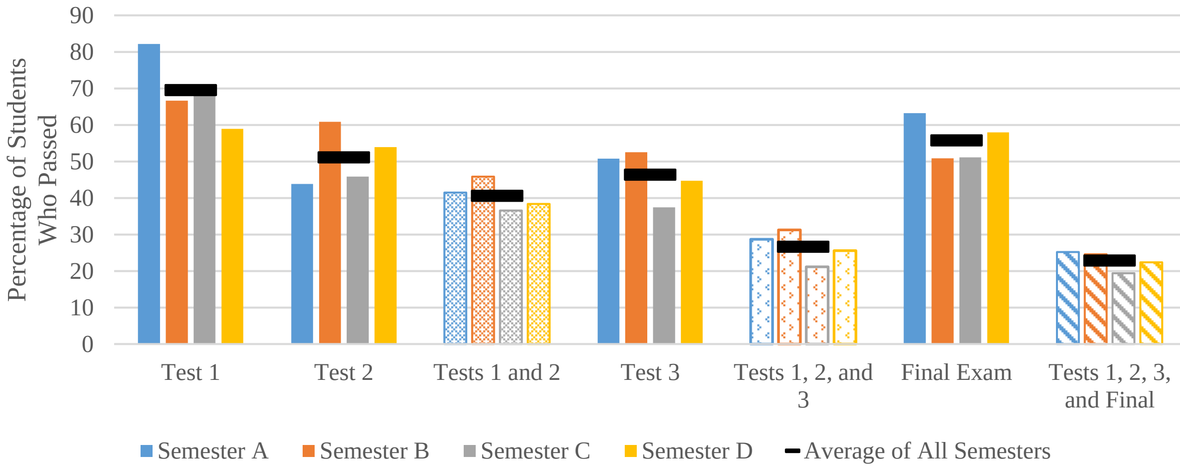

Figure 5. Percentage of Students who Passed One or More Tests for Semesters A-D.

Current Study

In the current semester *X*, 180 students were provided optional review problems prior to the second and third tests. The purpose of this intervention is to improve the students' grades for Tests 2, 3, and the final and increase the number of students who pass each test. These problems were not graded, but students were asked to submit answers for each problem on Top Hat. The problems were posted four days prior to the test with the answers revealed less than 24 hours before the test. The review included conceptual questions and problems requiring calculations. The material covered in the review was primarily focused on the new material for the next test but incorporated content from earlier in the course.

Only 38 students participated in at least one of the reviews for Tests 2 and 3, but all students had access to the problems and answers. Figure 6 shows the average grade percentage for the entire class and for the 38 review participants. The students who chose to complete and submit the review problems had a Test 1 average six points lower than the class. Once these students completed the reviews for Test 2 and/or Test 3, their average was higher than the class average for the second and third tests and for the final exam.

Figure 7 compares Semester *X* to the four earlier semesters using the black bars from Figure 5. The trends seen in the earlier semesters are not seen in semester *X*. For instance, more students passed Test 3 than Tests 1 or 2. It is unclear how the current study affected these results and more research is needed.

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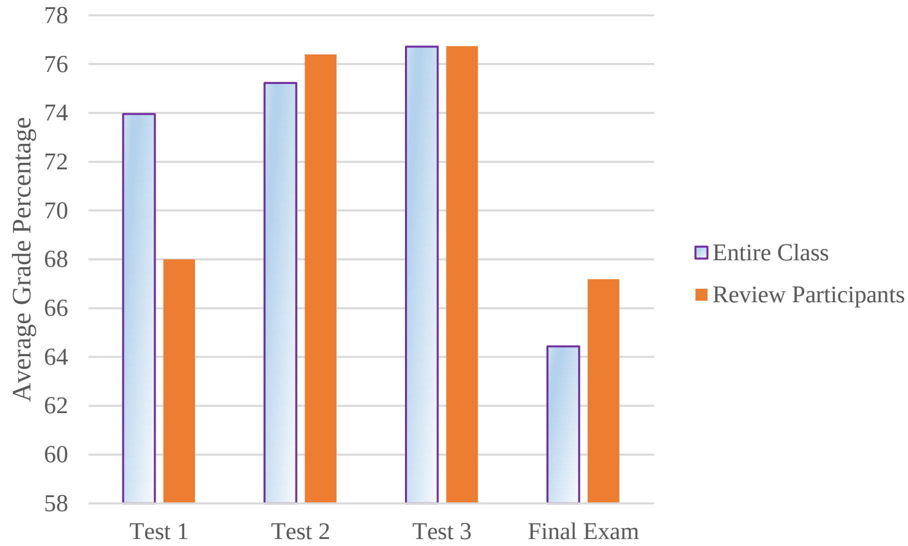

Figure 6. Average Test Grade for All Students in Semester X Compared to Study Participants.

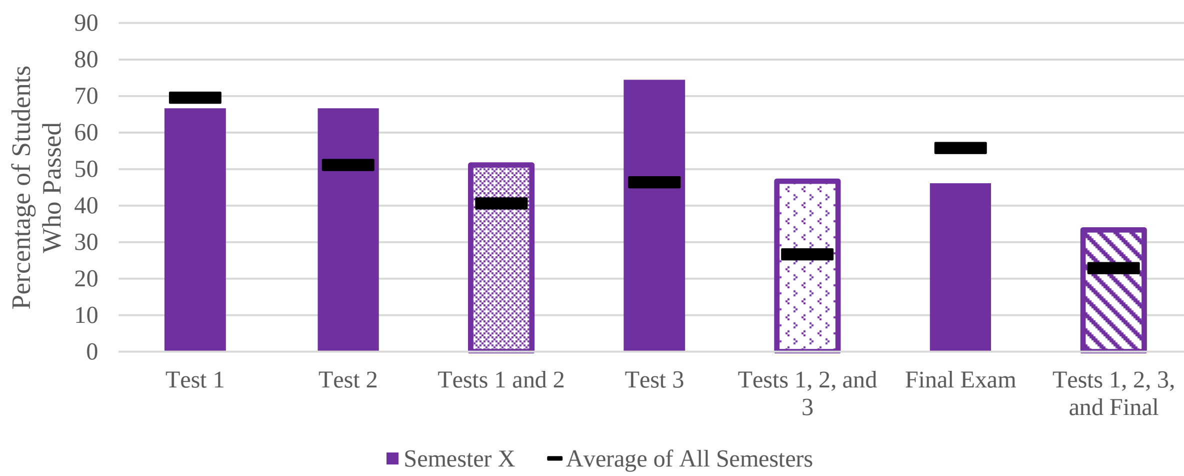

Figure 7. Percentage of Students who Passed One or More Tests for Semesters X.

Conclusions

The cumulative material of thermodynamics causes the course to become more challenging throughout the semester for many students. This research determines the percent of students who fully master the material based on test grades. Typically, test grades drop substantially after the first test so optional review problems were provided to students prior to the second and third tests. The group of students who participated in the review had a lower test average compared to the class for Test 1 but their averages were higher than the class after participating in the review.

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Future work will examine the types of review problems that are most helpful and how feedback on submitted solutions is best delivered.

References

1 Bain, Kinsey, Alena Moon, Michael R. Mack, and Marcy H. Towns, "A review of research on the teaching and learning of thermodynamics at the university level," Chemistry Education Research and Practice, Royal Society of Chemistry, 2014, 15, 320-335.

2 van Roon, P.H., H.F. van Sprang, and A.H. Verdonk, "'Work' and 'Heat': On a road towards thermodynamics," International Journal of Science Education, 2007, 131-144.

3 Li, Lei and Jennifer P. Pitts, "Does it really matter? Using virtual office hours to enhance student-faculty interaction," Journal of Information Systems Education, 20(2), 175-185.

4 Freitas, Frances Anne, Scott A. Myers, and Theodore A. Avtgis, "Student perceptions of instructor immediacy in conventional and distributed learning classrooms," Communication Education, 1998, 47, 366-372.

5 Semb, George, B.L. Hopkins, and Daniel E. Hursh, "The effects of study questions and grades on student test performance in a college course," Journal of Applied Behavior Analysis, 1973, 6, 631-642.

6 Cengel, Yunus, Michael Boles and Mehmet Kanoglu, Thermodynamics: An Engineering Approach, McGraw Hill, New York, 9th ed, 2019.

Nancy J. Moore

The author is a Teaching Assistant Professor at North Carolina State University in the Mechanical and Aerospace Engineering Department. She teaches undergraduate courses in the thermal-fluid sciences. She is the course coordinator for Thermodynamics I and has taught the course in the traditional lecture and flipped formats.

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