

## **Utilization of Recorded Student Narrated Solutions of Homework in Thermodynamics**

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### Abstract

Oral evaluation of subject area competency allows an instructor insight into the problem solving process students are applying to their coursework. Students were assigned to record themselves giving a brief narrated solution to one homework problem per textbook chapter. These narrated solutions were implemented into an introductory Thermodynamics course taken by all engineering students at Mercer University. These narrated solutions were graded for completeness, including having a coherent solution process and giving a sanity check of their work. The recorded narrated solutions were available for all students in the course to view for their own studying purposes. Average exam scores and standard deviations were tracked for student grades (out of 100%) for the three course exams; these statistics were averaged before and after implementing the narrated solutions. While average exam scores experienced small changes, the standard deviation of the means decreased by 0.78 on Exam 1, 0.70 on Exam 2, and 0.60 on Exam 3, when compared to semesters of similar length and structure. Additionally, students reported positive experiences with the narrated solutions in course evaluations. The tighter spread of student exam scores after implementing narrated solutions demonstrates a deeper class cohesion of understanding, which leads to more positive student outcomes.

### Keywords

Narrated solutions, student presentations, problem-solving skills, sanity checks.

### Introduction

Student coursework outside of the classroom has evolved rapidly in the last few decades. With the recent advent of various Internet services, students are free to study how they want and when they want. Group work allows students to practice teaching concepts in order to reinforce their own understanding. While these teaching opportunities are also possible in the classroom, they consume a significant portion of class time depending on the size of the lecture. These teaching opportunities are also possible via video recording, minimizing the impact of downtime between presentations.

This work presents the impact of adding student-narrated teaching assignments to an introductory Thermodynamics course taken by all engineering students at Mercer University. Students narrated an overview of the solution to one problem of their choosing per chapter of homework from the course textbook, *Fundamentals of Engineering Thermodynamics*, 8<sup>th</sup> edition by Moran, Shapiro, Boettner, and Bailey.<sup>1</sup> The effectiveness of these narrated solutions were evaluated by comparing exam statistics between seven sections with the narrated solutions and seven without. Potential positive impacts the narrated problems included improving exam mean

scores and decreasing the spread of scores. Additionally, notes from course evaluations are presented to highlight student perceptions of the narrated solutions.

## Literature Review

Oral presentation of homework solutions are typically evaluated in a classroom setting. While this is intimidating for many people, students often grow more comfortable in the classroom as the semester progresses, leading to better student-teacher outcomes.<sup>2</sup> Student outcomes vary depending on what is emphasized for an oral presentation. Students are often more worried about the correct answer than the solution process, which is not the correct approach to take in a course requiring significant critical thinking. By eliminating the “correct answer” as part of the graded material, students focus on other aspects of the problem-solving process which leads to more reflection on critical thinking skills.<sup>3</sup>

Based on previous studies on the effectiveness of student presentations, not only should student performance be evaluated, but student perception should be evaluated, as well. Research favors de-emphasizing the solution to problems, but the process of arriving at the solutions. Emphasizing the process will lead to stronger problem solving skills, which will benefit students even if they will never encounter the course’s subject area ever again.

## Methods

Exam data from 14 sections of EGR 235: Thermodynamics at Mercer University were compiled and compared over the course of 10 semesters. In all of the semesters considered in this study, students were given over 100 homework problems to complete distributed between six chapters. The students completed three regular exams in all but one of these semesters with the remaining semester only having two exams. While every semester had a final exam, often times it was optional as all of the exams are cumulative, making the final exam almost an iteration of the third exam.

For the first seven of the 14 sections considered, the course offered no other required deliverables for the students to complete (there was an additional list of recommended problems with no grade incentive attached). The other seven sections had a “narrated solutions” category as additional work to be completed outside of class. Narrated solutions are dictated answers to questions found in the textbook. Students were allowed to select any problem from the “developing engineering skills” section of the textbook problems, all of which had solutions which requires logic, skills, and concepts from the current chapter. Students were awarded credit for having the following seven elements: a summary of the problem statement, a sketch of the system(s) in the problem, key equations and concepts used, a state table (if it was relevant to the problem), a summary of the solution process, the solution to the problem, and at least one “sanity check” somewhere during or after the solution process. The sanity check provides students an opportunity to evaluate how realistic their solution or solution process. Each video had a soft time limit of 90 seconds to encourage students to focus on the critical points of their problem. Students were allowed to repeat any problems their peers had already completed, but the first student to submit a narrated solution for a particular problem got an additional bonus point on their score, giving students the potential to score 8/7 on each assignment. The narrated solutions were weighted around 10% of the overall class grade in each semester they were implemented.

In order to evaluate the effectiveness of narrated solutions, student performance on the regular exams was compared between semesters. In theory, if narrated solutions are effective, exam performance should improve. There is a significant variability between the same exam in different semesters due to different questions and the addition or subtraction of content due to the pacing of the course. Effective teaching tools will lower the variability of understanding in a class, which will be reflected in exam statistics. Thus, the standard deviation of exam scores between semesters was also considered as a measure of impact.

### Results and Analysis

The size of each class at the time of each exam is shown in Table 1. Number fluctuations are due to students dropping out or taking that test with another section. Most fall and spring classes are 20-30 students with some smaller classes in earlier fall semesters and a major outlier of 40+ students in the Spring 2022 section. The summer classes are much more varied in size most likely caused by a change in delivery method due to the COVID-19 pandemic.

**Table 1.** Number of students in each section at the time of exam. The break in the table represents when narrated solutions were implemented.

Section; Semester	$n_{Exam\ 1}$	$n_{Exam\ 2}$	$n_{Exam\ 3}$
1;1	21	17	19
2;1	11	13	11
1;2	7	6	n/a
1;3	31	31	28
2;3	32	31	28
1;4	15	14	14
2;4	29	28	25
1;5	20	19	19
1;6	26	25	24
2;6	25	24	22
1;7	45	45	44
1;8	15	15	15
1;9	27	26	26
1;10	11	12	12

The mean score of each exam,  $\bar{x}$ , for each semester is presented in Table 2. The first half of the scores represent semesters without narrated solutions, while the second half represents semesters with narrated solutions. Based on the means alone, student performance on average improved by 5.97% on Exam 1, 0.30% on Exam 2, and -.40% on Exam 3. The only exam that saw a significant change in scores was Exam 1. Sample standard deviation of the means,  $S_{\bar{x}}$ , for Exam 1 scores before narrated solutions were implemented was 8.01%, meaning that the improvement was less than a standard deviation. Thus, any significant hypothesis test will fail to prove that the narrated solutions improved average exam scores.

**Table 2.** Mean exam scores throughout each semester.

Section; Semester	$\bar{x}_{Exam\ 1}$	$\bar{x}_{Exam\ 2}$	$\bar{x}_{Exam\ 3}$
1;1	70.76	71.35	78.32
2;1	64.91	62.15	68.91
1;2	56.00	71.33	n/a
1;3	75.87	74.87	75.25
2;3	69.28	75.39	74.89
1;4	78.93	54.00	73.43
2;4	76.96	62.61	61.96
<b>Average; No Narr. Solutions</b>	<b>70.39</b>	<b>67.39</b>	<b>72.12</b>
1;5	88.35	70.79	67.84
1;6	69.46	62.92	71.83
2;6	68.92	65.22	66.60
1;7	77.49	61.96	60.47
1;8	77.93	72.93	70.80
1;9	76.19	70.73	87.19
1;10	78.18	69.25	77.33
<b>Average with Narr. Solutions</b>	<b>76.36</b>	<b>67.68</b>	<b>71.72</b>

Digging deeper into Exam 1, the first question provides a strong ground for comparison. The structure of the question is the same each semester: the question tests vocabulary by using technical vernacular to guide students to use appropriate relationships. While the question changes slightly each semester, the core structure and topic do not. Question 1 saw an improvement of 1.48%, far less than the overall exam.

Spring and fall semesters have the same class structure, but summer semesters do not. The summer semesters were 1;2, 1;5, 1;8, and 1;9. The summer semester takes the 14-week course and compacts it into five weeks. Summer sections of the course typically consist of students trying to get ahead, students needing to make up ground on graduation, and students who are retaking the course. Furthermore, Thermodynamics has been taught exclusively online during the summer as of semester 1;5 (Summer 2021). The exams for the online courses had the same structure, but the exams were nearly open Internet while the in-class exams were closed book with an equation sheet. Excluding the summer semesters, student performance on average improved by 0.23% on Exam 1, -1.52% on Exam 2, and -.60% on Exam 3. Additionally, the improvement on Question 1 of Exam 1 went down to -3.24%. Data presented here indicates that the narrated problems did not have a significant impact on average exam scores.

**Table 3.** Sample standard deviations of the means throughout each semester.

Section; Semester	$S_{\bar{x},Exam\ 1}$	$S_{\bar{x},Exam\ 2}$	$S_{\bar{x},Exam\ 3}$
1;1	3.98	2.60	3.18
2;1	5.52	3.05	5.05
1;2	5.39	3.89	n/a
1;3	2.79	2.76	2.63
2;3	2.90	3.29	2.40
1;4	3.71	6.12	4.76
2;4	2.88	4.62	4.33
<b>Average; No Narr. Solutions</b>	<b>3.88</b>	<b>3.76</b>	<b>3.73</b>
1;5	2.26	3.99	3.67
1;6	2.49	3.36	3.07
2;6	3.22	3.35	3.58
1;7	2.31	2.49	3.01
1;8	4.30	3.91	4.21
1;9	3.39	2.97	2.85
1;10	4.80	5.87	3.65
<b>Average with Narr. Solutions</b>	<b>3.25</b>	<b>3.70</b>	<b>3.43</b>

Sample standard deviation of the means,  $S_{\bar{x}}$ , for each individual exam are summarized on Table 3. Results are much more consistent with  $S_{\bar{x}}$  decreasing by 0.63 on Exam 1, 0.06 on Exam 2, and 0.29 on Exam 3. Excluding summer semesters, the drops become even more significant, with a drop of 0.78 on Exam 1, 0.70 on Exam 2, and 0.60 on Exam 3. The appreciable decrease in  $S_{\bar{x}}$  represents an improvement in collective student understanding. While exams may have peaks and troughs in difficulty due to varying questions, if student performance is more consistent, it is easier for the instructor to address gaps in understanding.

Every semester, students provided anonymous feedback via course evaluations. Students rated performance in various categories via a Likert scale as well as detailed feedback regarding the positive and negative aspects of the course. Some of the comments geared towards narrated problems included:

- “I like the narrated homework problems. It was a good way to interact with the class, and I otherwise wouldn’t have.”
- “The narrated solutions were helpful in understanding the process of problem solving. Although I didn’t enjoy them at first, I’ve learned a lot from doing them.”
- “Not the biggest fan of the narrated problems but I see how they are beneficial.”

Student perception of narrated problems is positive, meaning the students feel that they are getting something beneficial out of the recordings. Student perceptions are hard to measure using exam statistics, but the course evaluations definitely indicate more positive student outcomes with the course as well as better reinforcement of basic problem solving skills. In fact, some students commented on wanting to understand the problem solving process better:

- “I wish [instructor] emphasized more sanity checks when going through different kinds of problems.”

While sanity checks are emphasized in narrated problems, it is very encouraging to see students desire more where student may not have even considered sanity checks in the first place.

## Conclusions

Students recorded themselves narrating solutions to homework problems from the course textbook in EGR 235: Thermodynamics at Mercer University. The narrated problems provided students with an opportunity to learn the course content through teaching as well as provide a repository of solutions for their peers to review. While exam scores varied between similar semesters including narrated solutions and semesters that did not,  $S_{\bar{x}}$  decreased by 0.78 on Exam 1, 0.70 on Exam 2, and 0.60 on Exam 3. Furthermore, student feedback for narrated solutions were generally positive, suggesting the assignments were helpful for the course. Future work includes using more directed surveys to gauge student experiences, restructuring the assignments to work with additional subject areas.

## References

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