ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #36896

Impact of In-Class Demonstration on Student Performance in an Introductory Thermodynamics Course

Haejune Kim (Assistant Professor of Instruction)

Phapanin Charoenphol

Phapanin Charoenphol is an Assistant Professor of Instruction in the J. Mike Walker '66 Department of Mechanical Engineering at Texas A&M University. She earned her M.S., and Ph.D. from the University of Michigan, Ann Arbor. She teaches thermodynamics, fluid mechanics, engineering laboratory, and senior design studio courses. Her research interests include engineering education and targeted drug delivery. In 2022, she was awarded the ASME Best Teacher Award and earned the ACUE Certificate in Effective College Instruction.

Impact of In-Class Demonstration on Student Performance in an Introductory Thermodynamics Course

Abstract

The traditional lecture-oriented classroom has shown poor student knowledge retention and engagement, especially in a large classroom setting. An in-class demonstration is widely recognized as an effective method to engage students in the subject matter. This study examined how in-class demonstrations play a role in students' learning of undergraduate thermodynamics courses in mechanical engineering. Three demonstrations covering topics of energy conservation, property evaluation, and entropy were presented to a class. The modules were designed to demonstrate real-life examples for each course topic to promote student learning and engagement. After the demonstration, students were asked to discuss the topic as a group. The discussion questionnaires were developed to initiate discussions among students and help students gain conceptual understandings, reinforce ideas, and encourage students to think about various thermodynamics concepts creatively through real-world applications. After the group discussion, students' understanding was evaluated using several formative assessments. This study demonstrated that the in-class demonstrations significantly improved student performance for closed-book assessments. However, when the assessments were open-book, the in-class demonstration had no significant effect on the students' performance regardless of the type of questions, e.g., multiple-choice, true or false, and fill-in-the-blank. Overall, students expressed positive learning experiences with the in-class demonstrations and indicated a need for similar demonstrations in other courses.

Introduction

Principles of thermodynamics is a core course for mechanical engineering undergraduate students. Due to extensive applications of the subject matter, students in other engineering majors such as nuclear engineering, architectural engineering, industrial engineering, and civil engineering also enroll in this class as a required or elective course. Since this class typically has a large size with students with various educational backgrounds, instructors have often found it challenging to teach them effectively.

Traditional lecturing has been shown to associate with a poor knowledge retention rate, especially in a large classroom setting [1]. Previous works have demonstrated that students can gain knowledge more efficiently in an active learning environment [2-5]. Chickering and Gamson presented seven principles for good practice in undergraduate education, emphasizing the importance of interactive learning, efforts, and respect between students and faculty [6]. Prince also provided evidence for the effectiveness of active learning through collaborative and cooperative work [4]. Various active learning activities, such as quizzes, discussions, and experimentations, can be implemented to promote students' engagement [7, 8]. An in-class demonstration is widely recognized as an effective method to create an active learning space, engage students in the subject matter, and relate the concepts learned to real-world examples [9, 10]. To promote active learning in a thermodynamics course, various in-class demonstrations have been developed [11-14]. These studies focused on designing experiments and analyzing results, which were linked to learning outcomes associated with the course. However, there has been no systematic study on the effect of in-class demonstration on student performance. In this study, six in-class demonstration kits were developed for the thermodynamics course. The impact of the in-class demonstrations on student learning was investigated.

Methods

In-class demonstration kits

Six primary thermodynamics concepts are covered in the principles of thermodynamics class (MEEN 315) for undergraduate students in the mechanical engineering department at Texas A&M University. Since there is no laboratory course associated with the MEEN 315 course, six in-class demonstration kits were designed and created to relate each thermodynamics concept with real-world applications (Table 1). Each demonstration kit includes a portable and stand-alone experimental device, a video for in-class demonstration, an experimental manual, discussion questions, and a quiz. These materials are available for all MEEN 315 instructors on a local shared webpage.

Table 1: A list of thermodynamics concepts covered in the MEEN 315 course and topics of in-class demonstrations developed.

Thermodynamics Concepts	In-Class Demonstration Topics
1. Fundamental concepts	1. Temperature measurements
2. Energy and the First Law of Thermodynamics	2. Energy conversion and conservation
3. Evaluating Properties	3. Heat capacity and measurement of internal energy
4. The Second Law of Thermodynamics	4. The Second Law of Thermodynamics
5. Using entropy	5. Reversible and irreversible processes
6. Vapor and gas power systems	6. Gas Law

All in-class videos were designed to demonstrate real-life examples for each course topic to promote student learning and engagement. Instructors can conduct the demonstrations live in class as all experiments are portable. Alternatively, the demonstration videos (2-6 minutes long) can be played during class or as a take-home assignment. The experimental protocols are included in detail in the experimental manuals. In addition, theory, sample results, and discussion questions are also included to help instructors set up a class discussion. The discussion questions were developed to help students gain conceptual understandings, reinforce ideas, and encourage students to think about various thermodynamics concepts creatively through real-world applications. Finally, the quiz can be given to students individually or in groups to promote students' critical thinking skills and evaluate their understanding of the concept.

The following is a brief description of each in-class demonstration.

1. <u>Temperature measurements</u>

The temperature of a constant-temperature object was measured by various instruments such as a liquid in glass thermometer, a thermocouple, a bimetallic thermometer, a thermistor, and an RTD temperature sensor. The working principle of each device was explained, and the zeroth law of thermodynamics was demonstrated.

2. Energy conversion and conservation

A commercially available apparatus called Mechanical Equivalent of Heat (TD-8551A, PASCO Scientific, California, USA) was used to demonstrate an energy conversion from mechanical work to thermal energy and heat. Three different forms of energy were introduced. In addition, a calculation of the amount of energy transfer and energy storage was demonstrated, and a concept of the first law of thermodynamics was discussed.

3. Heat capacity and measurement of internal energy

A basic calorimeter set (TD-8557B, PASCO Scientific, California, USA) was primarily used to introduce a concept of heat capacity and internal energy. Energy transfer within the calorimeter, modeled as an adiabatic closed system, was demonstrated. An application of the first law of thermodynamics for a closed system was discussed and used to determine a specific heat capacity of an "unknown" metal. The measurement data was also used to demonstrate the increasing entropy principles of the Second Law of Thermodynamics.

4. The Second Law of Thermodynamics

A thermoelectric device (TD-8550A, PASCO Scientific, California, USA) was used to utilize the Seebeck effect to generate power for a small electric fan. Using the device, students verified the Kelvin-Planck statement of the Second Law of Thermodynamics. The thermoelectric device ran the fan only if the device had thermal interaction between two thermal reservoirs. Students also experimentally determined the nature of the cyclic system based on the total entropy generation in the isolated system.

5. Reversible and irreversible processes

A concept of entropy, irreversible and reversible processes and the increase of entropy principle were described through a demonstration of entropy examples in everyday life, such as mixing hot and cold water with food coloring, mixing marbles in a flask, pouring water in a cup, and collapsing block towers.

6. Gas law

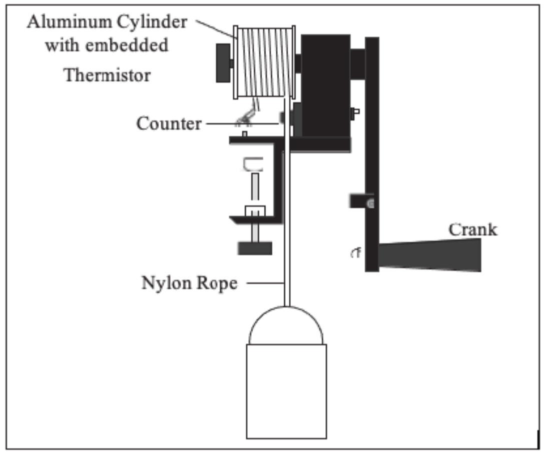
The objective of this experiment was to demonstrate Boyle's law and Charles' law. Boyle's law apparatus (TD-8596A, PASCO Scientific, California, USA) was used to illustrate the inverse relationship between pressure and volume of a gas at a constant temperature. Charles' law apparatus (TD-8572A, PASCO Scientific, California, USA) was used to verify the linear relationship between temperature and volume of a gas at constant pressure.

Implementation

In the Fall 2021 semester, three out of six demonstrations were presented to a MEEN315 class through video presentations during the class sessions. The three topics include topic 2 (Energy conversion and conservation), topic 3 (Heat capacity and measurement of internal energy), and topic 5 (Reversible and irreversible processes). Students were encouraged to review the experimental manuals made available through a learning management system (Canvas) before coming to the class. After the in-class demonstrations were presented, students were asked to discuss the topic as a group. The discussion questionnaires were developed to initiate discussions among students and help students gain conceptual understandings, reinforce ideas, and encourage students to think about various thermodynamics concepts creatively. After the group discussion, students' understanding was evaluated individually through quizzes with either a closed-book or an open-blook format. All quizzes were administered at a pre-scheduled time.

Samples of discussion and quiz questions on the Energy conversion and conservation demonstration.

An apparatus shown at the right is used to demonstrate the energy conversion from shaft work to internal energy. The work is performed by turning the crank, which turns the cylinder. As the cylinder turns, the friction between the cylinder and a nylon rope wrapped around the cylinder generates heat, thus converting the work into the internal energy of the cylinder.



The schematic provided by PASCO Scientific

1. Which of the following statements is true?
   a) The temperature of the aluminum cylinder increases.
   b) The amount of work must always be equal to the amount of internal energy.
   c) The energy absorbed by the cylinder could be greater than the work performed on it.
   d) Heat could be transferred between the aluminum cylinder and the surroundings.
   (Hint: The internal energy given to the aluminum cylinder by turning the crank is determined by measuring the temperature change of the aluminum cylinder.)

2. Does the amount of shaft work performed always equal the amount of heat absorbed by the cylinder? Include your explanation.

3. Is it experimentally possible that the heat absorbed by the cylinder could be greater than the work performed on it? Include your explanation.

In-class demonstration Feedback Survey

In the final weeks of the semester, students are invited to participate in an in-class demonstration feedback survey. The survey is anonymous and voluntary. The survey questions listed below were asked using a Likert scale from strongly disagree (1) to strongly agree (5).

1. Classes with in-class demonstrations are more engaging than traditional lecturing instructions.
2. In-class demonstrations helped me to better understand the concepts.
3. In-class demonstrations motivated me to learn more about the concepts.
4. I prefer watching videos of in-class demonstrations at my own pace.
5. I would want to see more in-class demonstrations for this class.
6. I would want to see more in-class demonstrations for other courses.
7. Compared to other courses in your major, do you find yourself wanting to learn more in this course?
8. Compared to other courses in your major, are you asking more questions about the material (in and outside of class)?
9. Compared to other courses in your major, do you talk/think more about the material in this course?
10. Compared to other courses in your major, do you find you are preparing better for this class?

Analysis, Results, and Discussion

In-class demonstrations were presented to the principles of thermodynamics course (MEEN 315) in a mechanical engineering department at Texas A&M University in the Fall 2021 semester. The class has 82 students with 6 different engineering majors, i.e., 59 students from mechanical engineering, 8 students from nuclear engineering, 6 students from ocean engineering, 5 students from architectural engineering, 2 students from civil engineering, and 2 students from industrial engineering. In a typical class session, the instructor used approximately 60% of the class time giving a lecture and 40% of the class time for in-class activities, including team problem solving, team discussion, and individual polling. This semester, five formative assessments were given to students, covering four primary concepts. Three concepts were taught through lectures along with in-class demonstration videos, while the other concept was taught through a lecture without in-class demonstration (Table 2). Quizzes 1 and 2 covered energy and the First Law of Thermodynamics and were given in a timed, closed-book format. Quizzes 3, 4, and 5 covered evaluating properties, control volume analysis, and using entropy were all given in a timed, open-book format (Table 2).

Table 2: Formative assessments given in the course

Quiz	Concepts	Assessment Format	In-class Demonstration
1 (Pre)	Energy and the First Law of Thermodynamics	Closed-book	No
2 (Post)	Energy and the First Law of Thermodynamics	Closed-book	Yes
3	Evaluating Properties	Open-book	Yes
4	Control volume analysis using energy	Open-book	No
5	Using Entropy	Open-book	Yes

1. Effect of in-class video demonstration on student performance

a. Closed-book formative assessment

Energy and the First Law of Thermodynamics are primary concepts in a thermodynamics course. These topics were covered early in the semester, and students were tested for their understanding of these topics twice, before (pre-quiz) and after (post-quiz) the in-class demonstration. Both quizzes covered the same concepts and had the same format (timed, closed-book), but they consisted of different questions.

The pre-quiz was administered after students learned about the concepts and completed a homework assignment. Students had no access to class resources during the quiz and the solution after the quiz. In the following class session, the in-class demonstration video about energy conversion and conservation was presented. After the demonstration, students worked in a team to discuss the concepts and solve problems related to the experiments. After that, students took the post-quiz in class individually. A total possible score of each quiz is 10 points.

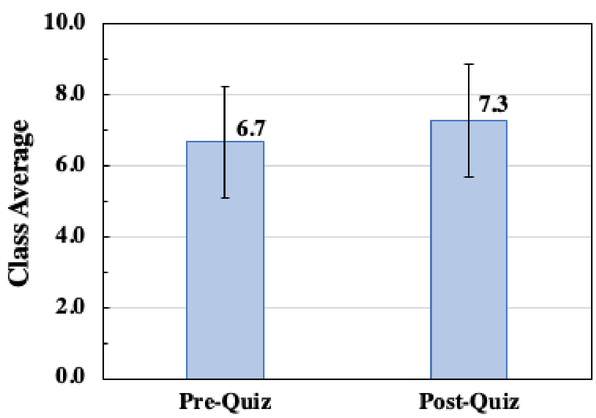


Figure 1: Class average on quizzes given in a timed, closed-book format, before (pre-quiz) and after (post-quiz) the in-class demonstration. Error bars show ± 1 standard deviation. $n = 81$.

Figure 1 demonstrates that the class averages for the post-quiz (7.3 ± 1.6 points) are higher than the pre-quiz (6.7 ± 1.6 points). When comparing individual student grades between the pre-quiz and the post-quiz, 54% of students performed better in the post-quiz, 19% performed the same, and 27% performed better in the pre-quiz. A one-tailed paired t-test comparing individual student pre-test and post-test scores demonstrates that students performed significantly better in the post-quiz (p-value = 0.002).

Overall, this result indicates that the in-class demonstration and activities can promote student understanding. The demonstration can help students relate the concept learned in class to real-life applications. Discussing the ideas and working in teams to solve related problems can engage students in higher-order thinking skills, including communications, collaboration, critical thinking, and problem-solving [15, 16]. These skills have been demonstrated to deepen the quality of their understandings and enhance learning efficiency [16].

b. Open-book formative assessment

A type of assessment format has been previously shown to affect student learning approach [17, 18] and student performance [19, 20]. Closed-book assessment is typically designed to assess factual recall, while open-book assessment is used to assess higher-order thinking and the ability to identify and access appropriate resources [18]. Since the in-class demonstration was previously shown to promote student understanding, our study further investigated their potential synchronous effect with the open-book assessment format on the student learning performance. In this study, three formative assessments (quizzes 3, 4, and 5) covered three topics were administered in a timed and open-book format (Table 2). Quizzes 3 and 5 were given after the in-class demonstration, while quiz 4 was delivered without the demonstration (Table 2).

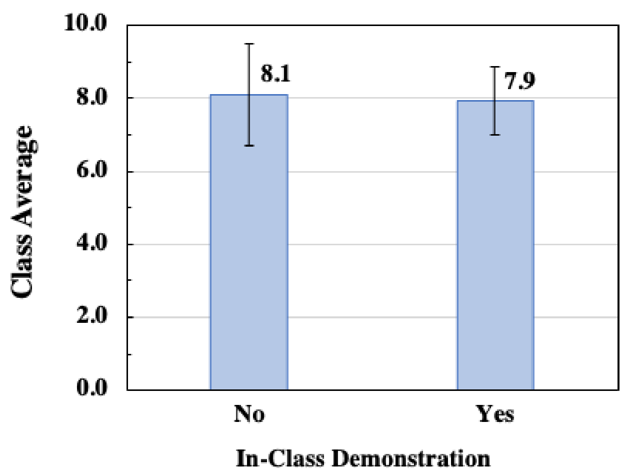


Figure 2: Class average on quizzes given in an open-book format, with (quizzes 3 and 5) and without (quiz 4) the in-class demonstration. Error bars show ± 1 standard deviation. n = 74.

The class averages for the quizzes given without (quiz 4) and with the demonstrations (quizzes 3 and 5) are 8.1 ± 1.4 points and 7.9 ± 0.9 points, respectively (Figure 2). A two-tailed paired t-test comparing the average scores of each student demonstrated that their scores on both quiz formats are not significantly different (p-value = 0.408). Unlike the closed-book format, this result suggests that the in-class demonstration does not significantly affect student performance when the assessment is given in an open-book format. Several plausible reasons could explain this finding.

First, the impact of the in-class demonstration on the open-book assessment was evaluated using the student scores from three different topics. Since each topic covers various concepts and has inequivalent complexity, the student performance could vary. In fact, the concepts covered in quizzes 3 and 5 (i.e., the quizzes given with the in-class demonstrations) were found challenging for most students. Many students struggled with evaluating and identifying proper thermodynamics properties and conceptualizing entropy. Thus, the average assessment scores on these topics generally tend to be lower due to these challenges. In addition, the effect of in-class demonstrations on student learning may be dampened in the open-book assessment. This is because students can still access similar resources and beyond on an open web during the evaluation, although the demonstration was not presented in class. Lastly, it has been shown that students have a lower testing anxiety level in the open-book assessment and tend to perform better [18, 19]. When the absolute student scores are relatively high, it may be intricated to observe the effect of the in-class demonstration.

2. Effect of Question Format on Student Comprehension

Undergraduate students have different learning processes and perceptions on the assessment format [21, 22]. To generate an assessment that complies with various student preferences, our formative open-book evaluations were designed to have multiple question types: True/False (T/F), Multiple-Choice (MC), Fill-In-The-Blank asking conceptual questions (FIB-C), and Fill-In-The-Blank asking numerical answers (FIB-N).

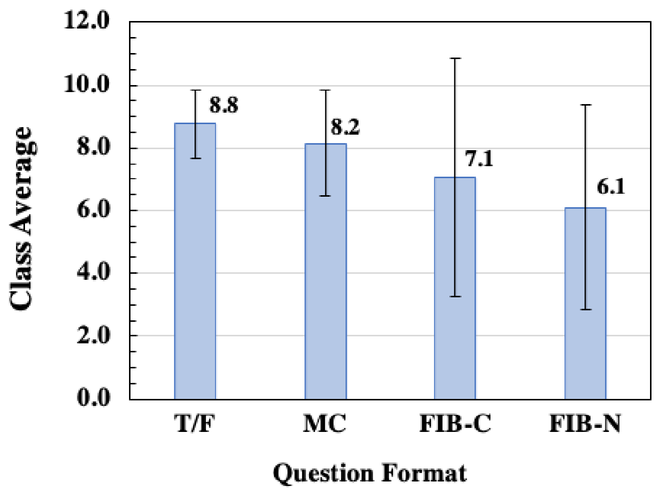


Figure 3. The class average on quizzes given with the in-class demonstration as a function of question format (True/false (T/F), Multiple choice (MC), Fill-in-the-blank asking conceptual questions (FIB-C), and Fill-in-the-blank asking numerical answers (FIB-N)) Error bars show ± 1 standard deviation.

The class averages from the quizzes given with the in-class demonstrations (quizzes 3 and 5) are categorized based on question formats. The averages are 8.8 ± 1.1 points for T/F, 8.2 ± 1.7 points for MC, 7.1 ± 3.8 points for FIB-C, and 6.1 ± 3.3 points for FIB-N (Figure 3). Although the averages shown were calculated from 74 students, low numbers of each question type were responsible for large standard deviations. An analysis of one-way ANOVA with Tukey post-test revealed that there was no statistical difference in the class average among different question formats. This result shows that the in-class demonstration does not favor student comprehension of a specific question type. The finding aligns well with existing works describing that the question format does not significantly impact student performance [18, 23]. Although the form of each question type may be different, the most important factor that affects student performance is likely what is asked on the question itself [18, 24].

3. In-class video demonstration impacts student learning experiences

A class survey was created to collect student feedback on how the in-class demonstration impacted their learning experiences and their motivations in the course. The survey responses were collected in the last weeks of the semester and were analyzed after the semester ended. Forty-one student responses were received.

In the first part of the survey, students were asked if the in-class demonstration helped enhance their learning compared to traditional lecturing instructions. Over 90% of respondents (strongly) agreed that classes with the in-class demonstrations were more engaging and helped them better understand the concepts. Eighty percent of respondents (strongly) agreed that the in-class demonstrations motivated them to learn more about the concepts (Figure 4). Overall, the in-class demonstrations appeared to be a great tool to promote student engagement, motivation, and learning.

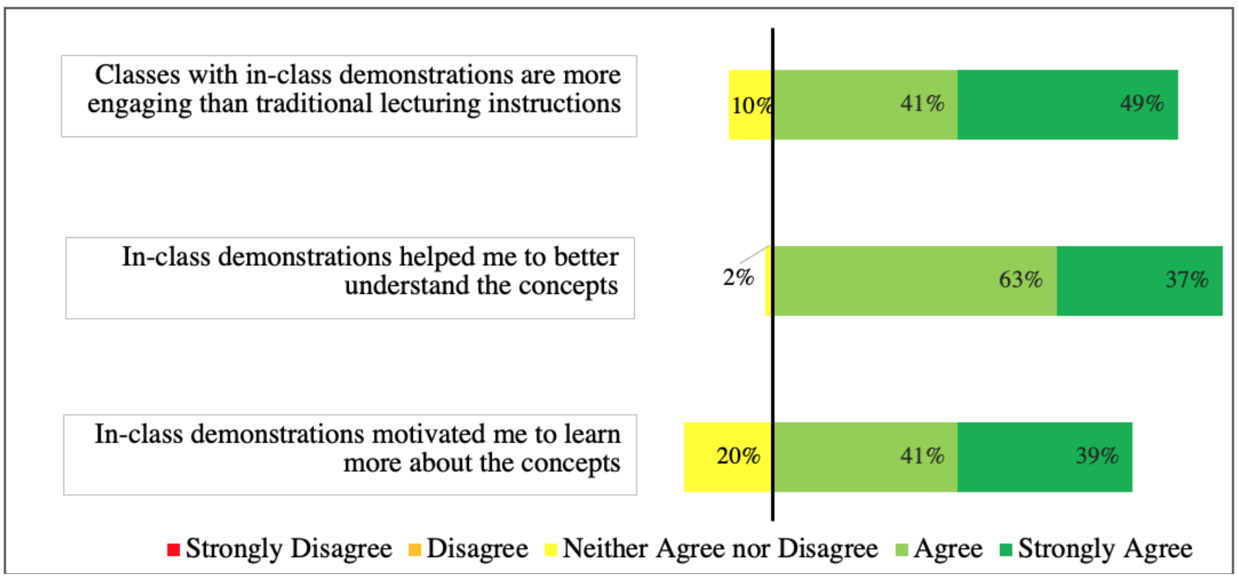


Figure 4. Student survey responses on the impact of the in-class demonstrations on their learning experiences (n = 41)

The students were also asked to provide feedback on their motivation and perception in this course (MEEN 315) compared to other classes in their majors. Ninety percent of respondents (strongly) agreed that they found themselves wanting to learn more in this course (Figure 5). A large percentage of students with high motivation could be due to both course formats and contents. During a typical class session, the instructor gave the lecture and assigned in-class activities. In addition, the in-class demonstrations were presented for three different topics throughout the semester. Both active learning components and the demonstrations related to real-world applications could make students engaged and feel a sense of belonging, which could promote them wanting to learn more in this course.

It is interesting to note that although most students showed interest in learning more in this course (90%), only approximately two-thirds of them actively asked questions and thought more about the course. Fifty-six percent of respondents stated that they asked more questions in and outside of class. Similarly, sixty-four percent of respondents indicated that they talked and thought more about the material. Seventy-three percent (strongly) agreed that they prepared better for this class (Figure 5).

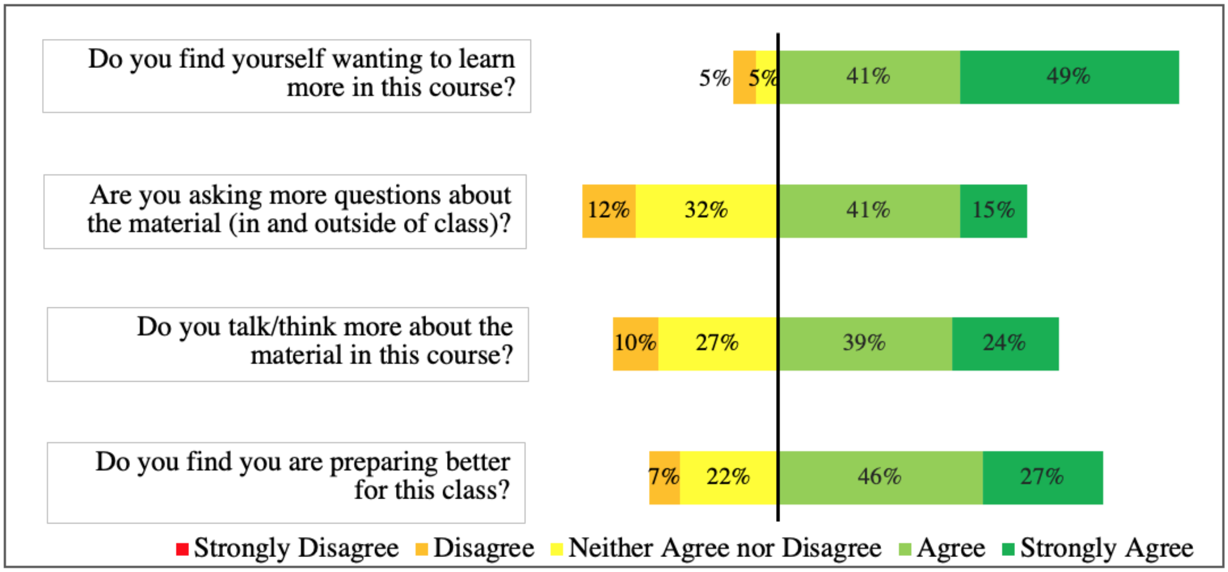


Figure 5. Student survey responses on their motivation and perceptions in this course (MEEN 315) compared to other courses in their majors. (n = 41)

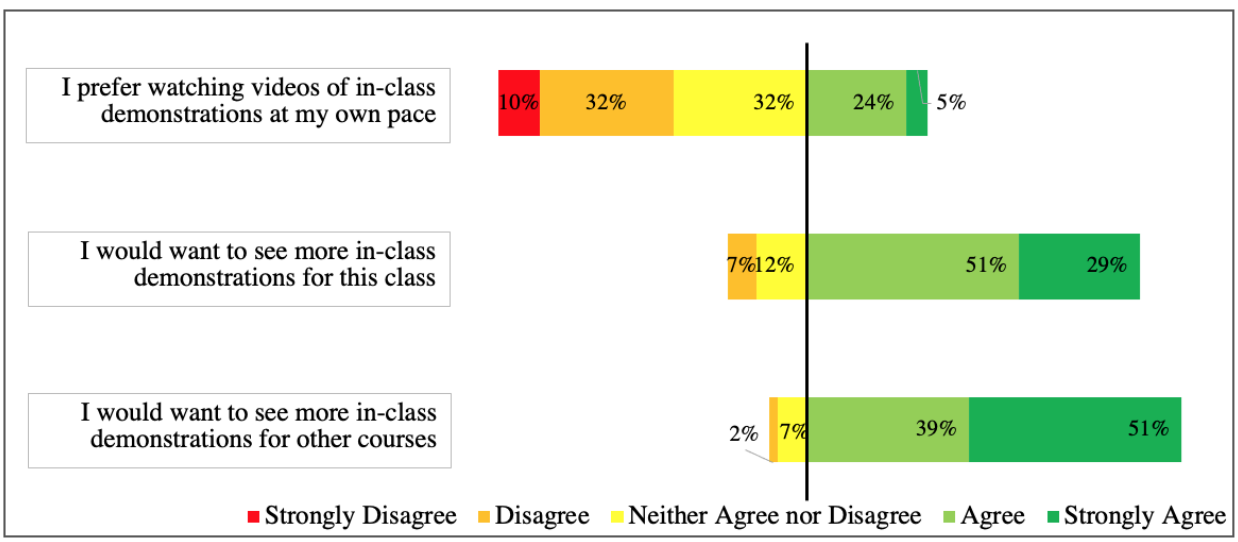


Figure 6. Student survey responses on their preferred format of the in-class demonstrations (n = 41)

The last part of the survey asked students about their preferred format of the in-class demonstrations. It appears that students had different preferences on how the in-class demonstrations were presented. Twenty-nine percent of respondents (strongly) agreed that they preferred to watch the demonstration at their own pace (Figure 6). Forty-two percent of respondents were satisfied with how the in-class demonstrations were presented during class, while the other thirty-two percent of respondents had no preference (Figure 6). Due to the various preferences, a video demonstration can also be made available for students to review outside class. Alternatively, the experiments can be demonstrated live in class to further increase students' engagement and hands-on experiences. Eighty percent of respondents stated that they wanted to see more in-class demonstrations in this class. Ninety percent of respondents (with 51% strongly agreed) said they wanted to see more in-class demonstrations for other courses. Overall, students expressed positive learning experiences with the in-class demonstrations and indicated the need for similar demonstrations in other classes. The demonstration implementation can be further refined to fit the course structure and students' needs.

Conclusion

In this study, the in-class demonstration kits were developed to promote student engagement and learning through creative discussion on real-world applications in the introductory thermodynamics course. The in-class demonstrations were shown to significantly improve student performance in closed-book assessments. However, when the assessment was open-book, the in-class demonstration had no significant effect on the students' performance regardless of the question types. Overall, students felt more motivated to learn, engaged in the class, and better prepared when the in-class demonstrations were presented. This study suggests that the in-class demonstration can be a great tool to promote active learning in a large class and increase student learning experiences.

References

[1] L. E. Bernold, J. E. Spurlin, and C. M. Anson, "Understanding our students: A longitudinal-study of success and failure in engineering with implications for increased retention," (in English), *J Eng Educ,* vol. 96, no. 3, pp. 263-274, Jul 2007, doi: DOI 10.1002/j.2168-9830.2007.tb00935.x.

[2] J. L. Faust and D. R. Paulson, "Active learning in the college classroom," *Journal on excellence in college teaching* vol. 9, no. 2, pp. 3-24, 1998.

[3] M. Prince, "Does active learning work? A review of the research," (in English), *J Eng Educ,* vol. 93, no. 3, pp. 223-231, Jul 2004, doi: DOI 10.1002/j.2168-9830.2004.tb00809.x.

[4] D. R. Webster, R. S. Kadel, and W. C. Newstetter, "What Do We Gain by a Blended Classroom? A Comparative Study of Student Performance and Perceptions in a Fluid Mechanics Course," (in English), *Int J Eng Educ,* vol. 36, no. 1, pp. 2-17, 2020. [Online]. Available: <Go to ISI>://WOS:000506204800002.

[5] D. Yang and K. Pakala, "Building an effect online thermodynamics course for undergraduate engineering students," 2017.

[6] A. W. Chickering and Z. F. Gamson, "Seven principles for good practice in undergraduate education," *AAHE Bulletin,* pp. 3-7, 1987.

[7] K. Altaii, C. J. Reagle, and M. Handley, "Flipping an engineering thermodynamics course to improve student self-efficacy," *American Society for Engineering Education,* 2017.

[8] R. D. Manteufel and A. Karimi, "Active learning in thermodynamics by leaving the front of the classroom," *ASEE Gulf-Southwest section annual conference,* 2017.

[9] M. Plumley, A. Foley, and E. Greene, "Practical demonstration units, using common components, for an introductory thermodynamics course," *American Society for Engineering Education,* 2009.

[10] D. R. Sokoloff and R. K. Thornton, "Using interactive lecture demonstrations to create an active learning environment," (in English), *Aip Conf Proc,* no. 399, pp. 1061-1074, 1997. [Online]. Available: <Go to ISI>://WOS:A1997BJ93N00121.

[11] H. I. Abu-Mulaweh, "Portable experimental apparatus for demonstrating thermodynamics principles," *International Journal of Mechanical Engineering Education,* 2004.

[12] R. Edwards, "An in-class demonstration used as an introduction to the first law of thermodynamics for an open system," *In ASEEIllinois/Indiana Section Conference. Angola, Indiana, USA,* 2013.

[13] K. Larsen, A. Hossain, and M. Weiser, "Optimizing the Curriculum in Thermodynamics and Heat Transfer with Better Labs, In-Class Demonstrations and Interesting Realistic Problems to Enhance Learning," (in English), *Proceedings of the Asme International Mechanical Engineering Congress and Exposition, 2015, Vol 5,* 2016. [Online]. Available: <Go to ISI>://WOS:000379703600028.

[14] P. Wattanakasiwich, C. Khamcharean, P. Taleab, and M. Sharma, "Interactive lecture demonstration in thermodynamics," *Lat. Am. J. Phys. Educ.,* vol. 6, no. 4, pp. 508-14, 2012.

[15] A. M. S. Hamouda and F. Tarlochan, "Engaging Engineering Students in Active Learning and Critical Thinking through Class Debates," (in English), *Proceedings of 6th World Conference on Educational Sciences,* vol. 191, pp. 990-995, 2015, doi: 10.1016/j.sbspro.2015.04.379.

[16] S. Zivkovic, "A Model of Critical Thinking as an Important Attribute for Success in the 21st Century," (in English), *International Conference on Teaching and Learning English as an Additional Language, Globelt 2016,* vol. 232, pp. 102-108, 2016, doi: 10.1016/j.sbspro.2016.10.034.
[17] D. Gijbels and F. Dochy, "Students' assessment preferences and approaches to learning: can formative assessment make a difference?," (in English), *Educ Stud-Uk,* vol. 32, no. 4, pp. 399-409, Dec 2006, doi: 10.1080/03055690600850354.
[18] S. Krasne, P. F. Wimmers, A. Relan, and T. A. Drake, "Differential effects of two types of formative assessment in predicting performance of first-year medical students," (in English), *Adv Health Sci Educ,* vol. 11, no. 2, pp. 155-171, May 2006, doi: 10.1007/s10459-005-5290-9.
[19] S. Ramamurthy, H. M. Er, V. D. Nadarajah, and P. C. K. Pook, "Study on the impact of open and closed book formative examinations on pharmacy students' performance, perception, and learning approach," (in English), *Curr Pharm Teach Lea,* vol. 8, no. 3, pp. 364-374, May-Jun 2016, doi: 10.1016/j.cptl.2016.02.017.
[20] J. B. Williams and A. Wong, "The efficacy of final examinations: A comparative study of closed-book, invigilated exams and open-book, open-web exams," (in English), *Brit J Educ Technol,* vol. 40, no. 2, pp. 227-236, Mar 2009, doi: 10.1111/j.1467-8535.2008.00929.x.
[21] A. Holzinger, S. Lettner, V. Steiner-Hofbauer, and M. C. Melser, "How to assess? Perceptions and preferences of undergraduate medical students concerning traditional assessment methods," (in English), *Bmc Med Educ,* vol. 20, no. 1, Sep 17 2020, doi: ARTN 31210.1186/s12909-020-02239-6.
[22] J. K. Hubbard, M. A. Potts, and B. A. Couch, "How Question Types Reveal Student Thinking: An Experimental Comparison of Multiple-True-False and Free-Response Formats," (in English), *Cbe-Life Sci Educ,* vol. 16, no. 2, Jun 1 2017, doi: 10.1187/cbe.16-12-0339.
[23] S. N. Smith and R. J. Miller, "Learning approaches: examination type, discipline of study, and gender," *Educational Psychology,* vol. 25, no. 1, pp. 44-53, 2005.
[24] L. W. T. Schuwirth and C. P. M. van der Vleuten, "ABC of learning and teaching in medicine - Written assessment," (in English), *Bmj-Brit Med J,* vol. 326, no. 7390, pp. 643-645, Mar 22 2003, doi: DOI 10.1136/bmj.326.7390.643.