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A COMPARISONOF STUDENT PERFORMANCE AND CONFIDENCE BETWEEN A TRADITIONAL AND A HYBRID THERMODYNAMIC CLASS

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ABSTRACT
This paper discusses the student performance and perception of two sections of the Thermodynamics course, a challenging class for college level engineering and science major students globally and at the studied institution. Comparison of student performance was also conducted across underrepresented and non-underrepresented students. One section was held in the traditional face-to-face format while the other hybrid. In the hybrid section, lectures were delivered in recorded videos through online learning management system Moodle while study sessions, review sessions, and exams were held in person in a classroom setting. It was discovered that while grades of students in the hybrid section were higher their confidence on the topics learned was lower than the traditional section. The findings of this study suggest offering thermodynamics in the hybrid format is a viable alternative to the traditional classroom format.

Keywords: *Thermodynamics; Hybrid Instruction; Mechanical Engineering; Underrepresented Minority*

INTRODUCTION
Thermodynamics is a branch of physics that deals with heat and its relation to energy and work. Understanding thermodynamics principles is essential in designing energy systems, such as power plants, engines, heating, ventilation, and air conditioning (HVAC), and refrigeration systems. It is usually a required class for college level mechanical engineering students.

While thermodynamics is a crucial class of the engineering curricula, globally many students not only struggle to understand the basic concepts such as work, heat, enthalpy, entropy, 1st and 2nd law of thermodynamics, but also have difficulties in applying the laws to real-life applications to perform engineering analysis. Patron (1998) and Junglas (2006) stated that college engineering students find thermodynamics impossibly difficult and the most hated subject. Anderson, Taraban, and Sharma (2005) believed that thermodynamics is particularly challenging because it contains many physical concepts that are unfamiliar students and it is normally taught without a laboratory experience. Meltzer (2004) discovered only 20% or fewer students were able to make effective use of the first law of thermodynamics, the foundation of the class, even after instruction. Cotignola et al. (2002) reported students had difficulties with the relation between heat and internal energy. Bullen and Russel (2007) reported only 50% of students at the University of Hertfordshire in the UK could pass the fluid mechanics and thermodynamics module at their first attempt.

At the studied institution, students here struggle with thermodynamics as much as literature has suggested if not more. Table 1 presents the DFW rate and its rank of thermodynamics at this institution for the past five academic years from 2013 to 2017. DFW rate refers to the percentage of students who received D+, D, D-, F, NC – no credit, IC – incomplete, and WU – unauthorized withdrawal. Thermodynamics has consistently been the class with the highest or the second highest DFW rate out of all mechanical engineering courses.

Table 1. DFW Rate and Rank of Thermodynamics at Studied Institution

Academic Year	DFW Rate	DFW Rate Rank
2017-2018	35%	1st
2016-2017	28%	1st
2015-2016	24%	2nd
2014-2015	26%	1st
2013-2014	21%	2nd

Various methods to improve student learning thermodynamics have been developed (Mulop et al., 2012). Georgiou and Sharma (2004) reported improvement in students' conceptual understanding with the implementation of active learning which increased student participation. Tatar and Oktay (2011) discovered mixed results on the effectiveness of problem-based learning on teaching the first law of thermodynamics. Liu (2011) developed a thermodynamics courseware to help student learning.

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The last decade witnessed a rapid increase in the number of students taking higher education learning experience online (Greenland and Moore, 2014) Unlike traditional face-to-face classes, the online environment exceeds standard synchronous education where students learn at the same time and place, and provides for asynchronous learning in which space and time are not barriers (Ku and Chang, 2011). At the same time, it is acknowledged that success in an online learning environment heavily relies on a student's ability to autonomously and actively engage in the learning process (Wang, Shannon, and Ross, 2013). Summers et al. (2005) measured students' final grades and satisfaction in an online introductory undergraduate statistics course in comparison to a face-to-face class. They reported that there was no significant difference in grades between the online and traditional classroom contexts. However, students enrolled in the online course were significantly less satisfied with the course than the traditional classroom students. Yang and Pakala (2017) explored effective pedagogy for teaching thermodynamics online. They recommended providing some face-to-face interaction opportunities for core engineering courses that cover a lot of complex concepts.

This studied institution is a Hispanic serving institution located in the southwest of the US where 43% of students are underrepresented minorities as of Fall 2018. They are usually also first-generation college students and work part-time or full-time to financially support themselves and their family. In an effort to reduce barriers of time and space for students while ensuring standard rigor, this study discusses student performance and their perception in a hybrid version of thermodynamics class in comparison to a traditional face-to-face section.

METHODS

The course

Two sections of thermodynamics taught by the same instructor in the Spring 2018 semester at the studied institution were used for comparison in this study. One was a traditional face-to-face section and the other hybrid.

Both sections covered the same content and utilized the online learning management system Moodle to post, collect, and grade homework, post class notes, and post homework solution. Students in both sections had access 24/7 to Moodle.

Not including the three exams which were all in-person, the hybrid section met with the instructor 5 times in the 15-week semester to prepare for midterm 1, debrief midterm 1, prepare for midterm 2, debrief midterm 2, and prepare for the final exam. While the class content was the same, the delivery method was different. In the traditional section, the instructor wrote notes on a Microsoft Surface which was connected to a projector while speaking. The delivery was synchronous. For the hybrid section, videos were created in a quiet studio directly from recording the Surface screen while the instructor spoke and wrote on it. These videos were posted on Moodle in 15 entries with each entry corresponding to approximately one week's worth of content. The asynchronous delivery of class content allowed students to watch the videos anywhere anytime from a computer or a mobile device.

Participants

All participants self-selected into each section. In order to reduce the bias from the student pool, students enrolled in the hybrid section were not aware it was hybrid when registering. They were informed it was hybrid on the first day of class and no student dropped the class. Each section had an enrollment of 47 students taking this class to fulfill their undergraduate degree requirement for Mechanical Engineering.

Instruments

Measure of Student Performance. Student performance was measured by calculating a cumulative score based on six homework assignments, two midterms and one final exam, all of which were graded out of 100 points. These exams tested students on their knowledge of 1st law, 2nd law, power cycles, refrigeration cycles, and heat cycles. Both sections shared the identical homework assignments and they were due at the same time via online submissions. Very similar midterms and the final exams were administered during the same weeks. For example, one section was tested on reheat cycle in the final and the other on regeneration cycle. Each section required students to come to campus to take every exam in-person at the same designated time and they were proctored by the same instructor. The two midterms were both 1 hour and 15 minutes long for each section and the final exam was 1 hour and 50 minutes long for both sections. The calculation of grade was also the same for both sections: 5% from homework, 30% from midterm 1, 30% from midterm 2, and 35% from the final exam.

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One grader graded the homework from both sections and one instructor graded all exams from both sections. Since attendance was not tracked or graded in the traditional section, online activities were not tracked or graded either in the hybrid section.

Measure of Student Perception. Student perception was measured by the course survey filled online by students voluntarily at the end of the semester. It was used to measure students' confidence on thermodynamics knowledge and students' perception on the course format. Students were also asked to comment on what they like or dislike the most about the class. This survey was developed by the Office of Assessment and Institutional Effectiveness at the studied institution. The survey form was slightly different for the two sections, but the only difference was that the survey given to the hybrid section asked two additional questions on the effect of flexibility on learning and the quality of instructional videos.

Analyses

This study answered two research questions. (1) Were there any differences in student performance as measured by homework and exam scores, and (2) were there differences in student perception as measured by course survey? Independent-samples *t*-tests were used to determine if there were significant differences between the two sections in terms of performance and perception.

RESULTS

Student performance

Table 2 presents the mean, standard deviation, and t-Test P-Value of the two midterms, final and cumulative score between the hybrid and traditional sections. All exams were graded out of 100 points.

All scores from both sections exhibited large standard deviations suggesting student performance spread to both ends. While the mean of every exam from the hybrid section was higher than the traditional section, midterm 1 produced the biggest difference of 11.1 compared to 3.3 of midterm 2 and 2.1 of the final. The hybrid section showed a mean of the cumulative score that was 4.7 points higher than the traditional section.

The P-Value from t-Test for midterm 1 was 0.04 indicating a statistically significant difference between the hybrid and traditional sections. But the P-Values from midterm 2 and the final exam indicate no significant difference between the two sections.

Table 2. Mean, Standard Deviation, and t-Test P-Value of Two Midterms, Final Exam and Cumulative

	Hybrid			Traditional			t-Test
	Mean	SD	n	Mean	SD	n	P-Value
Midterm 1	69.0	26.9	46	57.9	24.6	47	0.04
Midterm 2	71.7	25.7	46	68.4	27.1	46	0.55
Final Exam	62.5	23.6	43	60.4	24.9	42	0.70
Cumulative	64.6	24.4	47	59.9	23.7	47	0.34

Table 3 presents the mean, standard deviation, and t-Test P-Value of the two midterms based on student's minority status. URM stands for underrepresented minority which is defined as African-American, American Indian, or Latino/a. All other students including mixed-race students are categorized as non-URM.

Although no statistical difference was established between the two sections for URM or non-URM based, the mean of the hybrid section was consistently higher than the traditional section for both URM and non-URM in almost every exam. The only exception was the URM taking the final exam for which the mean of the hybrid section was 48.7. It was lower than the traditional section at 50.6. Overall, the hybrid section resulted in a higher mean of the cumulative score for both the URM and non-URM than the traditional section.

Table 3. Mean, Standard Deviation, and t-Test P-Value of Two Midterms, Final Exam and Cumulative Based on Minority Status

	Hybrid			Traditional			t-Test
	Mean	SD	n	Mean	SD	n	P-Value
Midterm 1 - URM	58.6	21.0	10	53.0	24.3	15	0.57
Midterm 1 – Non-URM	71.9	27.6	36	60.1	24.8	32	0.07

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Midterm 2 - URM	61.2	26.5	10	57.0	28.2	15	0.70
Midterm 2 – Non-URM	74.6	25.4	36	73.9	25.2	31	0.91
Final Exam - URM	48.7	24.0	9	50.6	28.6	13	0.86
Final Exam – Non-URM	66.1	22.7	34	64.8	22.2	29	0.82
Cumulative - URM	54.3	22.2	10	52.2	23.7	15	0.82
Cumulative – Non-URM	67.4	24.8	37	63.5	23.2	32	0.51

Student perception

32 students from the hybrid section and 30 students from the traditional section responded to the survey. Students were first asked to rate their confidence on a scale of 4 with 4 being very confident and 1 being not at all confident on four major topics in the class: 1st law of thermodynamics, 2nd law of thermodynamics, vapor power system, and gas power system. Results are listed in Table 4.

Table 4. Mean, Standard Deviation, and t-Test P-Value of Students' Confidence on Thermodynamics Knowledge

	Hybrid			Traditional			t-Test
	Mean	SD	n	Mean	SD	n	P-Value
1st Law of Thermodynamics	3.3	0.75	32	3.67	0.55	30	0.06
2nd Law of Thermodynamics	3.2	0.81	32	3.53	0.63	30	0.05
Vapor Power System	3.1	0.77	31	3.57	0.57	30	0.01
Gas Power System	2.8	0.77	32	3.31	0.60	29	0.01

Despite the fact that the hybrid section outperformed the traditional section in all three exams, students in the hybrid section felt less confident on all four topics compared to their counterparts. A statistically significant difference was established based on the t-Test P-Value for three out of the four topics: the 2nd law of thermodynamics, vapor power systems and gas power systems.

Students were also asked seven questions about their perception of the class with 4 being completely agree and 1 being completely disagree. Table 5 presents the results. Questions 2 and 4 did not apply to the traditional section.

While the hybrid section agreed on the class flexibility more than the traditional section, a statistical difference was not established. Students from the traditional section agreed more on question 3, quality of in-person instruction; question 5, class difficulty is appropriate; and question 6, satisfied with the help received. But only question 3 has a P-Value less than 0.05 indicating a statistical difference between the two sections. Students from the hybrid section strongly preferred the hybrid/online format of the class (mean = 3.0) than the traditional section (mean = 1.87) and a statistically significant difference was established from the t-Test P-Value of 3×10^{-4} which is much lower than 0.05.

Table 5. Mean, Standard Deviation, and t-Test P-Value of Students' Perception on Course Format

	Hybrid			Traditional			t-Test
	Mean	SD	n	Mean	SD	n	P-Value
1. Class schedule is flexible.	3.8	0.50	31	3.7	0.66	29	0.58
2. Flexibility helps learning	3.2	0.98	29				
3. Quality of in-person instruction	3.5	0.68	29	3.9	0.57	30	0.02
4. Quality of instructional videos	3.6	0.56	32				
5. Class difficulty is appropriate	3.3	0.75	32	3.6	0.78	29	0.29
6. Satisfied with the help received	3.1	0.81	31	3.3	0.86	29	0.32
7. Prefer to have this class partially or completely online	3.0	1.12	29	1.87	1.07	30	3×10^{-4}

Comments from the hybrid section shows what students liked the most about the class was the flexibility. One student said "I absolutely loved having this class as hybrid. I was disciplined in watching the videos and overall it was amazing having online lectures. I was able to pause, rewind, and fast forward through all the videos and that helped immensely. I would hope this option continues because it is what helped me pass this class". Another student stated "I was able to attend my internship during the designated class period, so I was able to have more time to study and absorb material without being tired. Also, having the ability to rewind a lecture is

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definitely one of the best things I have ever experienced.". What students disliked the most was the high requirement on the ability to autonomously engage in the class. One said "I end up forgetting about it since the class doesn't consistently meet up." Another said "Without there being many actual meet dates, I would put off the material."

Students from the traditional section mostly liked the clear lectures and examples given in class. One stated "I liked the amount of examples he went over to make sure we understood the section and going step by step, which was very helpful when I went back to look at my notes." Another stated "The in class lectures are great. I have learned so much of the material and how it applies on real life situations. The lectures are clear and concise.". What they disliked the most was the large amount of learning and grading. One student said what they disliked the most was "The amount of concepts and work that was condensed into how much students had to learn.". Another said "The grading scale is what I dislike the most. I wish that some more points could be located in the HW. This puts a lot of pressure in exams where they are worth 30%."

DISCUSSION

While students in the hybrid section scored higher in all three exams, they reported lower confidence and satisfaction regarding the class.

Instructor variable

While students in the traditional section received the lectures in person, students in the hybrid section received just the same lectures in the format of recorded videos. The only difference was students in the traditional section saw the instructor speak as a live person while students in the hybrid section did not see the instructor but only listened to him while watching the screen.

Course variable

There was no difference between the two sections in the calculation of grades, homework assignments, or coverage of materials. All exams were prepared at the same difficulty level. The only difference was the ability for instructor to answer questions in real time, but the instructor received very few questions from students in class from the face-to-face section.

Student variable

Students from both sections were self-selected. The hybrid section was not informed the class was hybrid during registration and none of the students dropped after knowing it was hybrid. It was done to control the student variable as much as possible.

All variables that may affect student performance and perception were carefully controlled except the lecture delivery method: face-to-face vs recorded videos. Therefore, it's safe to say the single most important factor affecting student performance and perception is lecture delivery method.

CONCLUSION

By carefully controlling variables, this paper examines how the lecture delivery method hybrid vs face-to-face affects student performance and perception in a challenging thermodynamics class.

It is discovered that the hybrid section outperformed the traditional section in all three exams. A statistically significant difference between the two sections was established for Midterm 1. Both URM and non-URM students in the hybrid section outperformed their counterparts in the traditional section except for the final exam taken by URM but no significant difference was established between the two sections for either URM or non-URM.

Contrary to their higher grades, students in the hybrid section reported lower confidence on all four major topics covered in the class and there was a statistical difference for three of topics between the two sections. Students from the face-to-face section reported higher satisfaction on in-person instruction and a statistically significant difference was established. They also reported higher satisfaction on class difficulty and help received although there was little difference in difficulty, or the help given between the two sections. Students in the hybrid section agreed slightly more than the face-to-face section that the class afforded them flexibility, but they much preferred the idea of having this class partially online or fully online than the face-to-face section. A strong

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statistical difference ($P = 3\times10^{-4}$) on their preference indicates taking this class in a hybrid section strongly affects their acceptance of the hybrid format.

In their comments, students in the hybrid section expressed they liked the flexibility and accessibility but struggled with self-regulation. This is consistent with what other researchers have found. Serdyukov and Hill (2013) stated online students are required to be more independent as the nature of online settings promotes self-directly learning.

A study conducted by US Department of Education (2009) revealed students learn slightly more from online than the traditional classroom approach, but they learn even more than either online or traditional when a hybrid approach is used. The results from this study confirmed hybrid students' better performance although no statically difference was established. Offering thermodynamics in hybrid format at least provides an alternative to students. It provides flexibility and accessibility that the face-to-face format cannot afford while student performance is not compromised.

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