ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #40590

LEARNING THERMODYNAMICS USING DISPLAY MODELS AND ANIMATIONS

Dr. ANEESHA GOGINENI, Saginaw Valley State University

LEARNING THERMODYNAMICS USING DISPLAY MODELS AND ANIMATIONS

ABSTRACT

This paper describes an effort to introduce display models and animations in thermodynamics course to improve student learning. Thermodynamics is a fundamental mechanical engineering course that leads to advance topics in engineering like heat transfer and energy systems. Students enrolled in thermodynamics course are either sophomores or juniors who lack knowledge in correlating theoretical concepts to thermodynamic applications (like pascals law, engines, heat exchangers, moving boundaries, nozzles, diffusers, air conditioners etc). The course is redesigned to incorporate new low-stake and high-stake assessments. The course instructor made efforts to improve student learning through active learning approach in a face-to-face class in three different ways: Using display models, integrated interactive app to increase student interaction in class and engage students in the subject, additional study videos were provided to help students understand thermodynamic tables. In an online course, efforts were made to improve student's understanding of the course material in two different ways: explain thermodynamic applications using animations and provide study guidance using structured homework's and graphic organizer. The effectiveness of these new teaching strategies was assessed using test scores and student feedback. The test results were compared with test results from traditional teaching class taught by the same instructor (author) from previous semester. Student feedback on new teaching methods were collected and satisfactory results were achieved. According to the course instructor, this study can help other instructors who use traditional teaching methods improve their student performance and increase student interactions in their courses.

KEY WORDS: Hands on Active Learning, Thermodynamics, Display models, Animations, Online teaching

1. INTRODUCTION

Thermodynamics is a pre-requisite for heat transfer and advanced thermal engineering classes. This course was originally taught by the course instructor (author) in traditional manner which covers the course material from the text book and solve problems on white board. Every semester nearly 16% to 20% of the class either fail the course or receive a D and repeat the class. Statistics from the traditionally teaching style also indicate that on an average 25% of the students in thermodynamics receive a C grade. Students attending this course are sophomore level students and they lack knowledge in real world applications. Hence the present study describes the use of display models and animations in thermodynamics course to increase student knowledge in real world thermal engineering applications. This paper also describes the use of active learning approach in face-to-face class and in an online class through interactive apps. The entire course is redesigned with structured course content shared to students via canvas. The author taught the course in a traditional format for 3years which included teaching theoretical concepts, equations, and solved application based textbook problems. Students who failed or scored a C grade in the course often struggled to correlate course content with real world applications. Hence these students could not solve problems. Students enrolled in thermodynamics course struggled with thermodynamic tables and did not know how to solve problems using systematic approach. The time allocated to teach thermodynamic tables during regular class time is 3hours. The entire course is based on thermodynamic tables and hence the time allocated for this topic seemed very minimal for the course instructor. Hence additional video examples on thermodynamic tables were recorded by the author and posted online in canvas. A systematic approach should be used to solve textbook problems and students often struggled to identify necessary equations and solve the problem. The author introduced graphic organizer which leads students through a structured design process while solving textbook problems. This study also anticipates increase in student retention and reduce failure rate in thermodynamics course. This teaching style can enhance higher order thinking approach in students and help them connect theoretical concepts with real world applications.

2. BACKGROUND AND MOTIVATION

After graduation, engineering students work in industries where they are required to work on different design projects with co-workers. Some of the challenges faced by students are not being able to relate textbook knowledge to real world design applications, work with others as a team and be an extrovert. It is very important to introduce students to project based (PrjBL), problem based (PrbBL) and active learning all together (POPBL) at an early stage of college education. POPBL can be incorporated in teaching and learning activities that can improve student's technical knowledge, communication skills and higher order thinking skills [1]. Hence, in the current study, the author conducted preliminary research on the following three modes of learning in mechanical engineering courses: *problem-based learning", "project-based learning" and "active learning"*.

Problem Based Learning

Ahmet G et al, investigated the effect of problem-based learning on students' academic progress. The authors chose to introduce enthalpy concept through PrbBL and the results indicated higher scores compared to traditional teaching. PrbBL also helped students improve their science process skills. However, this research is limited to one topic in thermodynamics [2]. PrbBL can be challenging if the course instructors fail to understand the learning process of PrbBL. The learning process consists of components that include objectives, material and methods of study, different strategies and evaluation procedure. Faculty at State University of Padang implemented PrbBL and noticed no difference in student test scores. However, after implementing PrbBL, faculty observed enthusiasm among students and difference in their learning outcomes. Therefore, Putra Z et.al, recommend faculty to develop Problem Based Learning model before implementing them in their courses [3]. Author Waddah A, strongly supports the need of redesigning courses based on social, economic and ethnic diversity of student population before implementing PrbBL. Experienced faculty should collaborate and form Active Learning Taskforce team to initiate, infuse and oversee the progress of the redesigned courses [4]. Author Rodriguez C et.al, conducted a review on problem-based learning and its application to the field of engineering education. Their study also suggests careful planning, organisation, teacher training and gradual exposure to PrbBL before implementing PrbBL. While evaluating PrbBL, course instructors should focus on objective measures and use qualitative forms to collect data [5].

Project Based Learning

Mechanical engineering jobs require employees to design projects and hence engineering educators should focus on preparing their graduates to meet current industry needs. Bringing industry to classroom will reduce design mistakes and help students understand real world applications. Research studies suggest introducing project-based learning in engineering design curriculum similar to industry format. Some of the challenges associated with PrjBL is lack of time. Students have to spend additional time to finish the design project and they sometimes need tutors help to understand some of technicalities of the design system [6]. Subrata R et.al, developed PrjBL in thermodynamic course. Fluid mechanics and heat transfer applications were integrated in the projects and students were asked to choose one project as part of their course project. Some of the design projects include determining blower size of a HVAC system, selecting nozzle diameter of a jet engine etc. This design model in engineering curriculum can help students meet certain educational outcomes defined by ABET. However, the authors indicated that students did not achieve outcomes to exceptional level [7]. A similar approach was executed by a mechanical engineering program at an urban research university. A design project was introduced in thermodynamics course curriculum and implemented it for four years by different instructors. The curriculum aimed at preparing students to perform well in senior level courses and increase retention. Thermodynamics is sophomore level course and students struggle to apply design concept in upper-level energy related courses. A strong foundation in design concepts should be introduced early in the course which can help students perform well in the senior level courses. This study recommends breaking down various topics and test student's knowledge in those areas [8]. Project based learning is limited to few design applications and hence student's understanding levels of the core concepts are still unknown.

Active Learning

Active learning is described in different ways and some of them include: a) actively engaging students with things and giving students an opportunity to think about the things, b) Learn content through reading and listening and reciprocating content, ideas and issues through talking and writing, c) increase student learning through active participation [9]. The author [9] used both traditional teaching and active learning in physics and thermodynamics course. The active learning method included small group, entire class discussion, solving quantitative and qualitative tasks collectively, just in time teaching assignments and flashcard learning kits. The outcome of this study indicated increase in student interaction and students were able to retain concepts in their long-term memory. Instructors also noticed change in student attitude and perception towards learning. Author Aaron R.B, observed similar results in student performance and student feedback after using active learning in his thermodynamics course. The author used multimedia elements like photos, videos and news that helped students learn important lesson topics. Some of the active learning techniques used in the course are think- pair- share, TV game show group boardwork. The author felt students were more engaged in an active learning environment when compared to traditional teaching format [10]. Another form of active learning technique that shows significant improvement in learning outcomes is Interactive lecture demonstrations (ILD). Georgiou H et al, divided students into four groups where two groups experienced ILD's and the other two groups experienced traditional teaching format. Instructor took a problem from thermodynamics and asked students to make a prediction on a worksheet individually. Students were then encouraged to discuss with peers and finally learn the solution to the problem from instructor through board work presentation. Instructor also recorded video lectures and made them available for students in blackboard learning management system. This provided additional study guidance to students, and they were able to ask more questions on the recordings [11]. In class collaboration based active learning have limitations in time and number of student participation. Hence, online interactive learning activities were proposed and evaluated. Some of these activities include interactive videos, quizzes, hot spots, online discussion, interactive presentations etc. The author [12] suggests instructors to get acquainted with learning management system (LMS) and embed online learning activities into LMS in an organized manner. Online teaching can be classified into synchronous and asynchronous formats. A different approach is required while integrating active learning in both the formats. Student learning and performance can improve by integrating Active Learning and Metacognition (ALM) strategically through structured activities. The author [13] offered thermodynamics course online in synchronous format and implemented ALM using two-part activity. The first activity is Explained Examples where students pair up and discuss given example problem. Students will then watch the instructor work through the example problem and then write a reflection paper on their observations. This experience will help students gain knowledge in the subject and apply that knowledge in future assignments. The second activity is Metacognitive activity where author used McCord and Matusovich taxonomy to observe and analyze students' response to a reflective prompt. The author noticed positive impact on student learning and hence recommends using this method in engineering education. Research studies indicate that synchronous online learning can be challenging for students as they lack interaction with fellow students and instructor. The self-paced learning format in synchronous teaching has impacted student learning and performance [14]. Hence, flipped classroom teaching has become a popular teaching format. Hyun J.C et al, explored flipped classroom setting in mechanical engineering course. This teaching format was implemented in mechanical engineering course to create an autonomy-supportive learning environment and increase active learning. In this format, students were required to watch pre-lecture videos prior to attending face to face lecture and engage in interactive problem solving. The flipped classroom format resulted in better student performance [15].

The author in the present study has carefully noted all the challenges associated with Project Based Learning and Problem Based Learning. Hence, display models were introduced in Thermodynamics course in a face-to-face class and animations were used in video lectures in an online class.

3. DIFFERENT TEACHING FORMATS

3.1 Traditional Teaching Format

Thermodynamics is a 3-credit mechanical engineering foundation course taken by sophomore or junior standing students. This course is a pre-requisite for upper division courses (advanced thermodynamics and heat transfer courses) taken by senior students. Heat transfer is a 4-credit mechanical engineering course which is a pre-requisite for capstone project. In a traditional classroom environment, the course instructor (author) explained the course content using theoretical concepts on white board, showed visuals of real-world applications and solved textbook problems on white board. After teaching the course for 3years in a traditional format, the author reviewed research articles on problem-based learning and introduced design-based homework's. Design-based homework requires students to answer knowledge-based questions on the course content and solve problems based on real world applications that they come across in their day-to-day life. This assignment only helped students understand that engineering courses connect to real world applications, but it did not help them solve the design problems. Fig.1, shows an example of design-based homework assigned to students to test their content knowledge on "Energy Analysis on Closed Systems".

1. How much power does your refrigerator, TV and air conditioner consume in a day? (3 Points)
2. Which one of the above three should be replaced with energy efficient model? Why? (2 Points)
3. Write energy balance equation for the above three devices when all three of the above devices are in living room (assume living room is closed system) (2 Points)
4. Assume your living room is 4m x 5m x 7m and it is insulated with initial temperature of 6°C. It is then heated using a rigid steam heating tank that has a volume of 12L and is filled with steam at 200kPa and 200°C. A 125W fan is used to distribute the air in the room. The pressure of steam drops to 100kPa after 45min as result of heat transfer to room. Determine the internal energy in the room after 45min. (8 Points)

Fig. 1 Example of design-based homework

3.2 New Teaching Format Face to Face (Redesigned Course)

The author incorporated display models or props to demonstrate fundamental thermodynamic concepts like the first law of thermodynamics, moving boundaries, energy balance, heat transfer modes, conservation of mass applications, etc as shown in Fig 3. Students were divided into 6 groups with 5students in each group to solve the active learning problems prepared from the display models. Here is an example of an activity given to students on pascals law demonstration.

Activity on Pascals Law: Use Pascal's Law demonstrator to determine the ratio of force F2/ F1 as shown in Fig.2 below. Measure dimensions d1 and d2 [d1 and d2 are bigger and smaller diameters of the syringe cross-section respectively]. Fluid is filled with air.

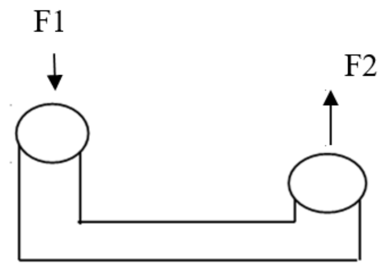

Fig. 2 Pascal's Law

IC engine display model is used to demonstrate moving boundary condition and explain the difference between closed system rigid bodies and energy analysis of closed systems with boundary. Jet engine display model is used to demonstrate mass and energy analysis of turbine and compressor application. A mini refrigerator is used as an example to explain second law of thermodynamics and coefficient of performance of refrigerator.

Fig. 3 a) Example of Turbine & Compressor **b)** Example of Moving Boundary IC Engine **c)** Example of Pascal's Law **d)** Example of Refrigerator

Thermodynamic tables (steam tables) play a major role in thermodynamics course and course instructor (author) spends a lot of time in each semester explaining the phase change concept, state properties and its correlation to steam tables. The four properties (specific volume, internal energy, enthalpy and entropy) available in steam tables are applied to different thermal energy applications. Due to time constraint, only few problems can be solved in class, and this covers few combinations of identifying phase changes and their dependence on subsequent properties. Hence, students struggled to use thermodynamic tables during quizzes and exams. This affected student test scores and overall performance. To increase student knowledge on thermodynamic properties, additional study guidance was provided to students using online lecture videos. Several examples were discussed in those videos which covers multiple combinations of phase changes and their dependence on properties. Online quizzes were given to students via canvas to test their knowledge on thermodynamic tables. In addition to thermodynamic tables, students also struggled to note given information and energy balance equation while solving problems. The course instructor felt the need to help students understand the process of problem solving and hence a graphic organizer is provided as shown in Fig.4 below.

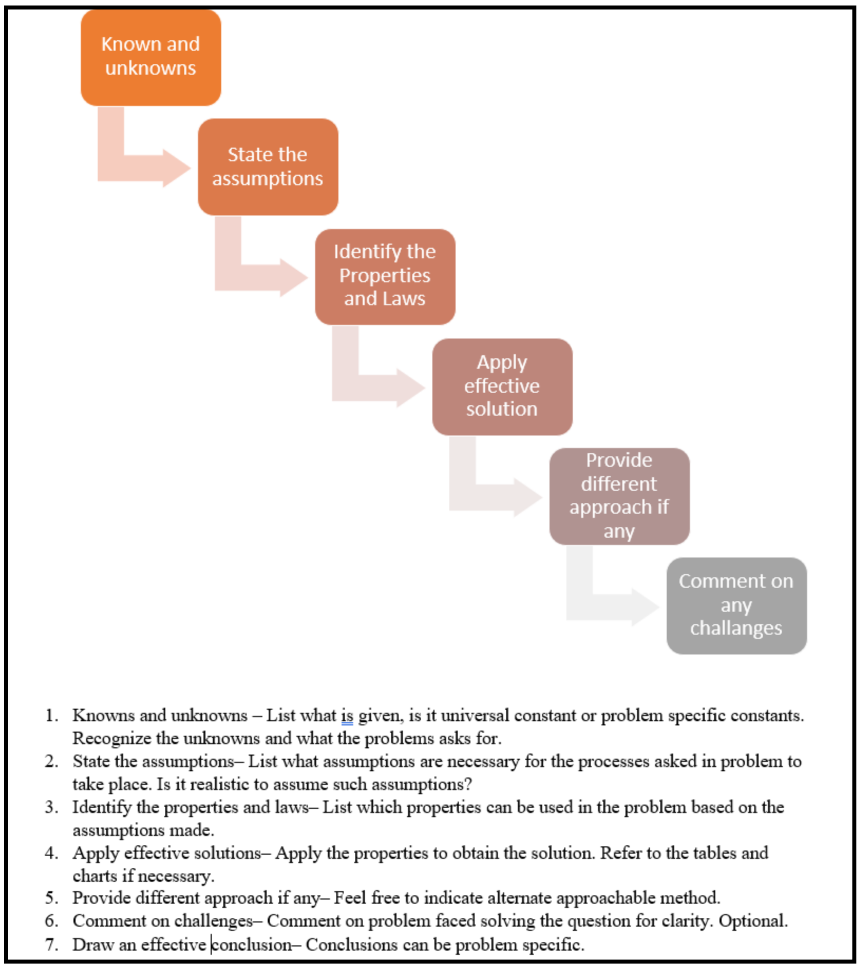

Fig. 4 Graphic Organizer to Explain Problem Solving Process

The graphic organizer explains a step-by-step process to solve problems in quizzes and exams. In the first step, graphic organizer shows that it is best practice to note given information, identifying unknowns and knowns while solving problems. In thermodynamics, it is very important to write energy balance equation and state assumptions like no heat transfer, no kinetic energy and no potential energy which is the second step in the graphic organizer. In step three, the author suggested students to identify phase changes and apply them to subsequent thermodynamic property. This step will provide guidance to solve the application problem. Sometime, while solving problems in thermodynamics course more than one method can be applied and hence step five is presented to help students realize that there will be one solution and multiple methods to solve a problem. Step 6 is optional to students, and this is given to establish communication between instructor and students to learn more about student challenges during quizzes and exams. The final step is to mark the final solution in the exam.

Students in thermodynamics course are usually in sophomore or junior standing and they exhibit minimal interest in classroom interaction. The author introduced an interactive app (Socrative) to increase student engagement. Students can login through their phone/laptop for few minutes to answer pop quiz questions given by the course instructor. Student feedback on this interactive technique was collected through anonymous survey conducted at the end of the semester (details are discussed in section 4 student assessment on new teaching techniques).

3.3 New Teaching Format Online (Redesigned Course)

Online teaching was never considered as an alternative for face-to-face learning in engineering but one thing that COVID has taught us is the importance of teaching online in any educational sector. Animation based lectures were introduced by the author to increase student enthusiasm in learning course material in an online format. The animations videos were chosen similar to display models used in face-to-face class. These animation videos were embedded in power point presentation and demonstrated through online recorded lecture. Fig.5 below is an example of animation explaining moving boundary condition. The additional online videos on thermodynamic tables and graphic organizer were provided to students in online course as well.

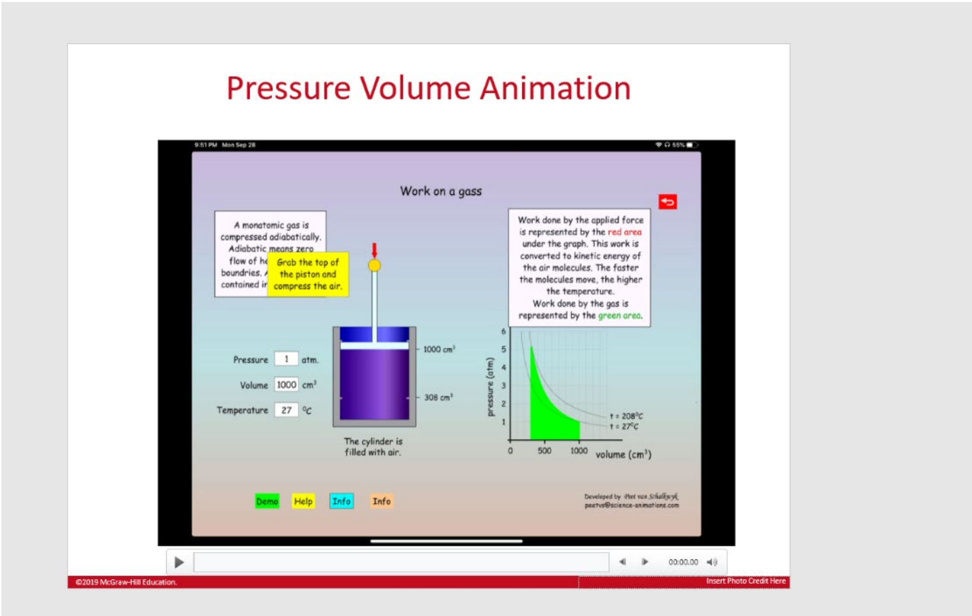

Fig. 5 Animation on Moving Boundary Condition

The lecture in the online course is divided into two segments, echo360 recorded lessons and live interaction via Microsoft teams. In recorded videos the entire course content is covered using power point presentations, embedded animations, and few textbook problems. Recorded videos can be boring and disengaging to students if the video length is more than 20min. Hence, the author prepared short videos and added polling questions to include active learning in online course. Students are required to join Microsoft teams meeting and the course instructor spends additional time to summarize the topics covered in that week. Additional problems are assigned to students to works in groups of 4 in breakout rooms. In breakout rooms, students can use Microsoft white board to solve problems, or they can discuss and work through the problems in their own notebooks.

4. STUDENT ASSESSMENT ON NEW TEACHING TECHNIQUES

These new teaching techniques require further assessment to verify their ability to continuously improve learning environment. Informal survey questions were prepared by the course instructor for both face-to-face and online class, and they were presented to the institutional research board. The board approved the survey questionnaire and students provided their feedback anonymously. The two teaching formats (Face-to-Face and online) are taught by the same course instructor in two different semesters. The survey questionnaire for the new face to face teaching format and online formats are provided in Table 1 and 2 below.

Table 1 Informal Student Survey Questions and Ranking Scale in Face-to-Face Thermodynamics Course

	Respond to questions below using the following scale					
	1-Strongly disagree, 2-moderately disagree, 3-undecided, 4-moderately agree, 5-Strongly agree					
Questions	**Online Videos on Thermodynamic Tables (Steam Tables) and Quiz**					
1	Video lectures helped me review more examples	5	4	3	2	1
2	Quizzes prepared me well for using thermodynamic tables	5	4	3	2	1
	Socrative App					
3	Socrative app motivated me to participate and listen in class	5	4	3	2	1
4	The questions asked through the app helped me study the material	5	4	3	2	1
	Interactive Lecture Demonstrations (ILD) with Display Models					
5	The interactive demonstrations(using different display models) are suitable and related to the lectures	5	4	3	2	1
6	The ILDs (interactive lecture demonstrations) helped me understand the lectures better than a traditional class	5	4	3	2	1
	Graphic Organizer (Step by step procedure guidelines given to solve the problem)					
7	Graphic organizer helped me solve problems without difficulty	5	4	3	2	1
	Self Assessment					
8	This method of teaching increased my interest in the field of mechanical engineering	5	4	3	2	1
9	I believe in the importance of adequate study habits	5	4	3	2	1
10	I believe in the need of creative thinking, problem solving and design skills to survive in engineering	5	4	3	2	1

The survey results from a face-to-face course as shown in Fig. 6 below indicate more than 90% of the students either mildly or strongly agree that video lectures and quizzes on thermodynamic tables help them understand steam tables. More than 85% of students think the quizzes conducted through interactive app increased student engagement and improved their learning. 83% of the students are in agreement with the statement "display models are suitable and related to lectures". 16% of the students were not sure about this statement and this could be due to their lack of familiarity with real world applications and their connection to textbook content. Majority of students in the same control group on the contrary, felt that interactive lecture demonstrations using display models were better than traditional classes. Feedback on the importance of using graphic organizer to solve textbook problems did not reach the course instructors expectation. Only 65% of the students agreed that the graphic organizer helped them understand the problem-solving procedure. The other group of students had a different opinion, and this could be due to their prior knowledge on problems solving strategies. The self-assessment survey question has 100% positive response rate, and this shows students have positive opinion on interactive lectures and higher order thinking skills. Students also believe that adequate study habits can increase their confidence and learning skills.

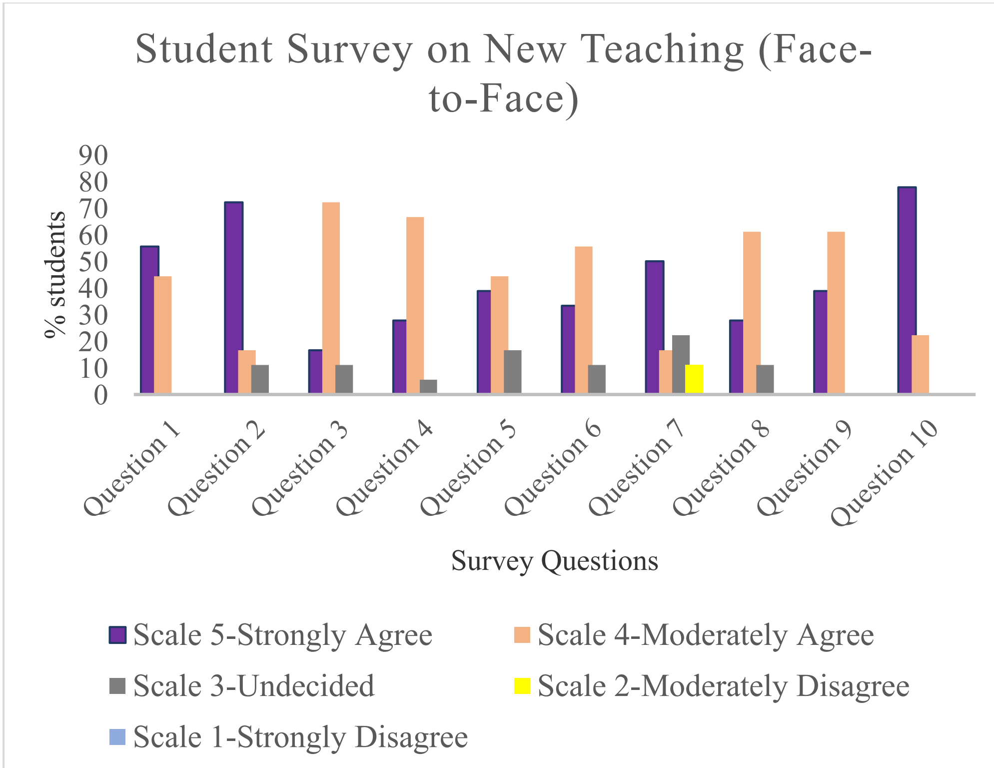

Fig. 6 Student Survey on New Teaching Strategies in a Face-to-Face Thermodynamics Course

The survey questions for face-to-face and online teaching formats are slightly different. Some of the common questions for both teaching formats are providing additional videos on thermodynamic tables and graphic organizer in canvas. The instructor used display models as part of the interactive lecture demonstrations in face-to-face format and in an online class animations were replaced with display models. The lecture content in an online class was recorded via echo360 software tool and additional problems were discussed via Microsoft teams. Online exams can be proctored using testing browsers like Respondous LockDown Browser. However, the author in the present study used Microsoft teams for live proctoring. Students in the teams meeting were required to turn their camera on and show their desk from a distance as shown in Fig.7 below. The Microsoft teams live proctoring rules are given below:

- Show your desk space and that it is free of phone and do not leave your desk during the exam
- Your equation sheet should be visible in the webcam (try as much as you can to make your desk and your face visible during the exam
- All exams are copyrighted and students who post exam questions on Chegg will receive a zero on the exam/quiz.
- When you are ready to scan your work, please send the instructor a message in the Teams chat window. As soon as the instructor responds to your message, you are allowed to use your phone to scan the answer paper and submit your work on the submission site.

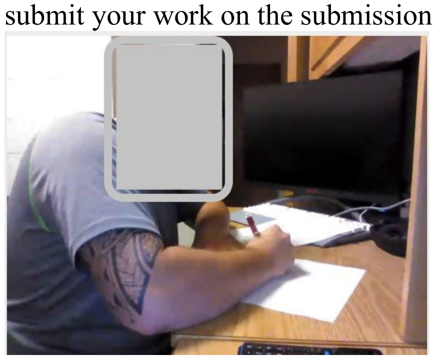

Fig. 7 Microsoft Teams Proctoring Guidance

Students often struggled to use testing browsers due to technology issues and hence it is very important to include questions about proctoring in the student survey. Students also had difficulty working in groups in breakout sessions and hence few questions on breakout rooms via teams were included in the survey.

Table 2 Informal Student Survey Questions and Ranking Scale in Online Thermodynamics Course

	Respond to questions below using the following scale					
	1-Strongly disagree, 2-moderately disagree, 3-undecided, 4-moderately agree, 5-Strongly agree					
Questions	**Online Quizzes and Exams**					
1	I prefer online Teams Proctoring over Respondus monitor and lockdown	5	4	3	2	1
2	Exams and quizzes helped me test my content knowledge					
	Microsoft Teams Live Sessions					
3	Breakout sessions motivated me to participate in class	5	4	3	2	1
4	Teams live participation problems provided additional learning material					
5	Summary of recorded sessions discussed in Team's Live session were useful					
	Echo360 Video Lectures					
6	The video lectures helped me review material at a flexible time	5	4	3	2	1
7	I prefer recorded lectures over face-to-face lectures	5	4	3	2	1
	Echo360 Polling					
8	The questions asked through the polling helped me study the material	5	4	3	2	1
9	I prefer using this tool in other classes as well	5	4	3	2	1
	Animations					
10	The animations used to explain different concepts are suitable and related to the lectures	5	4	3	2	1
11	The animations helped me understand the lectures better than a traditional class	5	4	3	2	1
	Self-Assessment					
12	This method of teaching increased my interest in the field of mechanical engineering	5	4	3	2	1
13	I believe in the importance of adequate study habits	5	4	3	2	1
14	I prefer face to face learning over online teaching	5	4	3	2	1
15	I believe in the need of creative thinking, problem solving and design skills to survive in engineering	5	4	3	2	1

Fig. 8 below provides informal student survey data on online teaching strategies. Teams proctoring introduced in the online courses received positive response from students when compared to online proctoring browsers. These browsers are very expensive, and students had technology issues while using this tool. More than 85% of the students felt quizzes and exams conducted every week provided them an opportunity to self-assess their course content knowledge. Students are required to watch recorded videos before participating in the Microsoft teams live lecture. The author summarized weekly course content at the beginning of the class and then directed students to join breakout rooms for problem solving. 78% of the students agree that the summarized course content helped them learn the material in an effective manner. To increase interaction among students the author forced students to work in groups via Microsoft team's breakout sessions. Only 72% of the students felt motivated to participate in class with other group of students. Additional problems were assigned to students in the breakout sessions to add more knowledge on the subject material and 78% of the students found this technique useful. The author recorded lectures using Echo360 and majority of the students felt that this method provided them an opportunity to review material at a flexible time. However, 47% of the students still prefer face-to-face lectures over recorded lectures. Polling questions were embedded in the recorded videos to increase engagement, but majority of the students disagree that this technique helped them study for the course. Display models in face-to-face class was replaced with animations in an online class and 80% of the students agree that this approach explained different concepts from the course. However, only 52% of the students liked this approach over a face-to-face class and the remaining students still prefer face-to-face course format. The self-assessment results are very similar for face-to-face and online class.

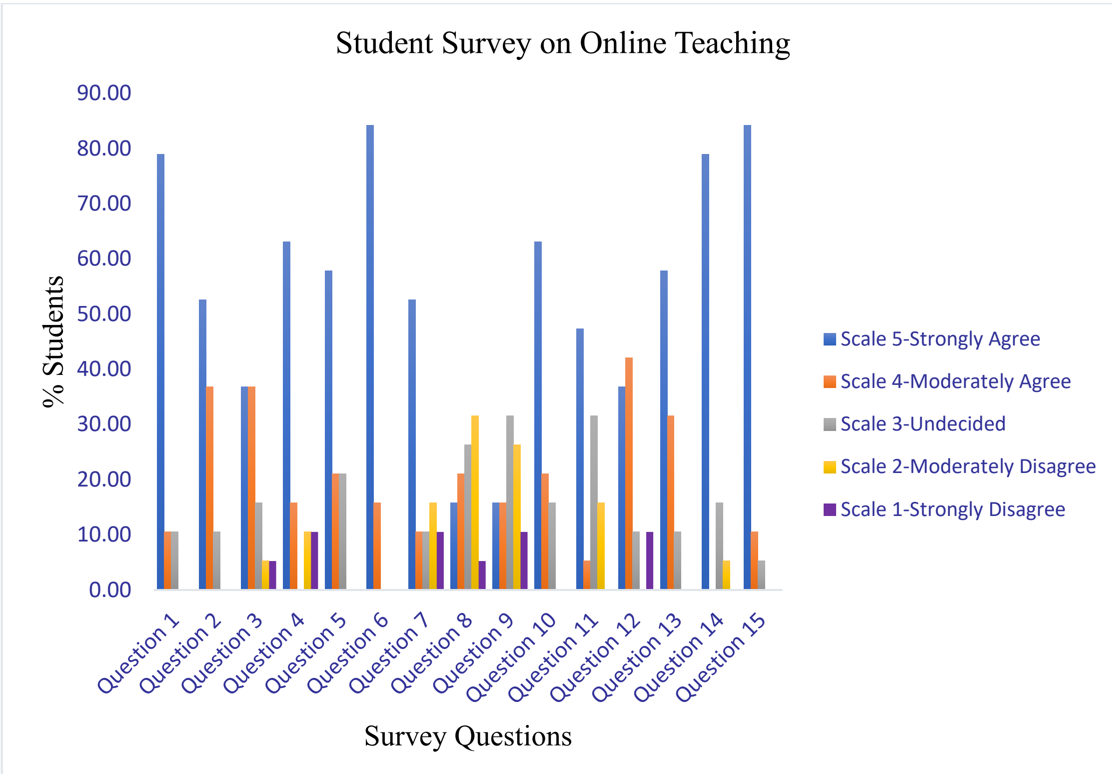

Fig. 8 Student Survey on Online Teaching Strategies

5. RESULTS OF STUDENT PERFORMANCE

In addition to student feedback on the new teaching strategies, it is important to assess student performance which further evaluates the efficacy of new teaching methods. Student performance using display models, graphic organizer and supplemental videos on thermodynamic tables was better than traditional teaching format. The average test scores of 25 students in traditional teaching format were compared to average test scores of 25 students in the redesigned course as shown in Table 3. The syllabus covered for each of these tests remained the same for both control groups (traditional and redesigned courses). The online course structure is slightly different from a face-to-face course structure. The course instructor took online teacher training and the sessions provided guidance on canvas course structure and best practices for online format. One suggestion includes weekly or bi-weekly quizzes and exams to help motivate students to watch recorded lecture sessions on time. Students in general procrastinate watching recorded videos, but multiple quizzes and exams forced them to watch videos as per the suggested course schedule. Table 4 below provides quiz and test average scores of 25 students in an online class. Student performance in an online class did not meet instructor’s expectations. Thermodynamics course was offered online for the first time and students had difficulty transitioning from face-to-face teaching format to online. Even though majority of the student feedback from the survey indicates the teaching strategies were engaging and informative, student outcomes dropped in comparison to redesigned face-to-face course.

Table 3 Comparing Student Outcomes between Traditional Teaching and Interactive Teaching

Tests	Traditional Teaching	Redesigned Course ILD Display Models
Test Average 1	76.6%	81.7%
Test Average 2	70.4%	73.9%
Test Average 3	60.6%	71.3%
Test Average 4	73.4%	78.4%
Test Average 5	75.7%	82.5%
Final	70.7%	76.7%

Table 4 Student Performance in an Online Course with Animations and Microsoft Teams Interaction

Average Tests and Quizzes	Online Course with Animations
Quiz 1	92.0%
Test 1	90.0%
Quiz 2	76.8%
Test 2	54.4%
Quiz 3	76.6%
Test 3	81.5%
Quiz 4	66.6%
Test 4	79.5%
Quiz 5	77.4%
Final	63.3%

6. CONCLUSIONS

Mechanical engineering courses are highly structured, and knowledge driven with emphasis on course level and program level outcomes. Each course in the mechanical engineering program can use a different pedagogical strategy to increase student performance and engagement. The author in the present study taught thermodynamics course in traditional format for three years. Students in this course often struggled to solve real world application-based problems using thermodynamic tables. The course instructor purchased display models that replicated thermal engineering applications and utilized them as part of the course content. Recorded videos on thermodynamic tables were added to canvas course as a new strategy to support underprepared students. The author implemented similar teaching format in an online course by replacing display models with animations. The assessment tools in the present study are student feedback through informal survey and student test scores. The assessments indicate positive response to face-to-face course format with display models and animations in an online class. However, students test scores in an online class were lower than the face-to-face class. Thermodynamics course was offered online for the first time in mechanical engineering department, and this is one of the biggest challenge in the current study. A small group of students still struggle to work in groups in breakout rooms in the online course. These teaching strategies should be continued in the online course and the course instructor plans to continue to teach thermodynamics course online to obtain best practices in an online class. A flipped classroom model can also benefit students as this model provides students an opportunity to interact with professor in a face-to-face format and watch online recorded lectures at a flexible time. The author will further investigate different teaching models by promoting active learning in online/hybrid classes and compare student test scores.

ACKNOWLEDGMENT

The author received funding for this research through Dow Professor Grant funded by Herbert H. and Grace A. Dow Foundation. This grant provides funding to full time tenure track faculty who implement and evaluate innovative teaching projects.

REFERENCES

[1] Ziwei, C., "Active Learning through Combination of Project-Based Learning with Problem-Based Learning in Engineering Education," *Int. Conference on Social Science and Higher Education* (ICSSHE) (2015). **Conference Proceedings**

[2] Ahmet, G., Cetin, D., Esen, G., "Teaching of the Concept of Enthalpy Using Problem Based Learning Approach", *Procedia-Social and Behavioral Sciences,* 197, pp.2390-2394, (2015). **Conference Proceedings**

[3] Putra, Z.A., and Dewi, M, "The Application of Problem-Based Learning in Mechanical Engineering", *Materials Science and Engineering*, 306, (2018). **IOP Conference Series**

[4] Waddah, A., "Problem-Based Learning in Engineering Education: Reflections, Practices and Challenges", *Proceedings of the ASEE North Midwest Sectional Conference*, (2010). **Conference Proceedings**

[5] Rodriguez Gonzalez, C.A., and Fernandez, B.J.M., "A Review of Problem-Based Learning Applied to Engineering", *International Journal on Advances in Education Research*, ISSN: 2340-2504, vol.3, pp.14-31. (2016). **Online Scholarly Journal Article**

[6] Ramesh, K., and Duncan, M., "Project based learning in an engineering design course developing mechanical engineering graduates for the world of work,", *Procedia. CIRP 91,* pp. 565-570, (2020). **Conference Proceedings**

[7] Subrata, R.,Karim, J.N., Berry, K.J., "Development of a Project-Based and Design Driven Thermodynamics Course", *American Society of Engineering Education,* (2002). **Conference Proceedings**

[8] Sivakumar, K., and Razi, M.N., "Project based learning in Introductory Thermodynamics*", American Society of Engineering Education*, (2009). **Conference Proceedings**

[9] Zdenka, K., Petr, K., " Active Learning in Advanced Undergraduate Course of Thermodynamic and Statistical Physics", *Science in Education,* Vol.8, Iss.1, pp.65-80, (2017). **Online Scholarly Article**

[10] Aaron, R.B., " Using Multimedia and Active Learning Techniques to Energize an Introductory Engineering Thermodynamics Class", *American Society of Engineering Education/IEEE*, (2001). **Conference Proceedings**

[11] Georgiou, H., & Sharma, M.D., "Does using Active Learning in Thermodynamics Lectures Improve Students Conceptual Understanding and Learning Experiences?," *European Journal of Physics, vol.36,* (2015). **Online Scholarly Journal Article**

[12] Kalyana, C.C., "A Novel Framework for Active Learning in Engineering Education Mapped to Course Outcomes", *Procedia Computer Science,* 172, pp. 28-33, (2020). **Open Access Article**

[13] Andrea, G., "Reflecting while doing: Integrating Active Learning and Metacognitive Activities in a Fully Online Thermodynamics Course", *American Society for Engineering Education*, Paper ID# 37110 (2022). **Conference Proceedings**

[14] Sabine, F., Julia, M., and Sebastian, S., "Impact of Synchronous and Asynchronous Settings of Online Teaching and Learning in Higher Education and Students' Learning Experience During COVID-19", *Frontiers in Psychology*, (2021). **Open Access Article**

[15] Hyun, J.C., Kejie, Z., Cho, R.L., Debra, R., and Chuck, K., "Active Learning through Flipped Classroom in Mechanical Engineering: Improving Student's Perception of Learning and Performance", *International Journal of STEM Education*, (2021). **Open Access Article**