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Engage to Retain: Active Learning at the Conclusion of Traditional Lectures

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Abstract

In traditional classroom settings, student engagement tends to decline during lectures, which is most noticeable near the end of class, when the focus of students turns on the clock rather than the lecture content. This disengagement often manifests as premature packing up of materials and early departures from the class. The final 10 minutes are often ineffective. This paper describes the impact of concluding lectures with an active learning activity to increase student attention, participation and learning. The activities can range from asking students to summarizing key lecture points, identify confusing topics, applying concepts, or solving problems in detail. All of these have been used, with the most effective end-of-class activity being problem solving. The authors conclude that ending lectures with active learning activity has improved student attentiveness by 13 to 20%, and increased opportunities to emphasize the important points in the course. Exam scores were found to be 10 to 20% higher compared to previous semesters when active learning activities were not used to conclude lectures.

Introduction

The authors of this paper have been teaching thermal sciences courses in the mechanical engineering program that The University of Texas at San Antonio (UTSA). They have been using various techniques to engage students in class activities for many years[1, 2, 3, 4, 5]. One technique attempted has been the use of “Flipped Classroom” concept by requiring students review the assigned course materials prior to attending the scheduled lecture sessions. Using this approach, most of lecture time was utilized for students to solve example problems as group, or individual activities. For the group problem solving activities, students in the classroom were divided into several groups, and students in each group work together to solve a given example problems. The role of instructor was primarily to answer questions and provide useful hints to aid students to solve example problems. One of the authors used flipped classroom concept prior to the COVID pandemic period and found the approach not be very satisfactory[4]. In this case, students were asked to read the assigned sections of the textbook and review the lecture slides related to the specific reading assignment, prior to attending each lecture. The intend was to use the early part of the lecture period for students to solve example problems and use the latter part class period for students to either respond to true/false, multiple-choice questions, or solve a quiz problem showing detailed solution. This approach did not yield successful results, as a good portion of students had not read the assigned textbook materials or reviewed the lecture slides, prior to attending each scheduled class period. This required the instructor to spend a good portion of class time lecturing on the reading assignment, instead of students solving example problems. The other author employed a Flipped Online Learning with Synchronous Meetings in an Engineering Thermodynamics Course during the COVID pandemic period and found the approach satisfactory for the online class. The main problem with flipped classroom is that students are familiar with traditional lectures, typically dislike doing more work and dislike listening/interacting with many of their classmates when the classmates display whole range of poor social skills, and dislike it when the instructor appears to be doing less by not lecturing. Students are more comfortable when instructor lectures, other students remain silent, and they listen. Students prefer passive learning, or at least being passive during class meetings.

Active Learning

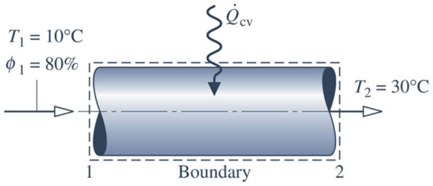
In traditional classroom settings, student engagement often tends to decline during lectures, which is most noticeable near the end of class, when the focus of students turns on the clock rather than the lecture content. This disengagement often manifests as premature packing up of materials and early departures from the class. The final 10 or 15 minutes are often ineffective. This paper describes the impact of concluding lectures with an active learning activity to increase student attention, participation and learning. The activities can range from asking students to summarizing key lecture points, identify confusing topics, or applying concepts to solve a problem. All of these have been used, with the most effective end-of-class activity being problem solving. A lecture is closed a few minutes early and a problem is presented, sometimes in the form of a pop quiz.

Several years prior to COVID pandemic, both authors started using true/false or multiple-choice pop questions to assess students' understanding of fundamental concepts.[2,3]. Originally ParScore-Scranton were used to evaluate student responses to quiz solution. But a few years prior to the COVID pandemic, they began using adaptive questions and electronic pooling devices (eg., I-clicker) to engage students and to measure students' mastery of the fundamental concepts. Electronic pooling devices, became a more effective tool that promoted active learning in the classrooms. Instructors were able to gain real-time feedback on student comprehension of the fundamental concepts. The followings are a few examples of true/false or multiple-choice questions used in thermodynamics and heat transfer courses during active learning exercises.

1. Air in a closed system undergoes a process from 300 K, 1 bar to 900 K, 5 bar. Select the best option describing this process:
   (A) $dm/dt = 0$, (B) $dE/dt = 0$, (C) $dS/dt = 0$, (D) all (A), (B) and (C)
   (E) none of the above

2. For each of the following phrases:
   i) In a vapor power cycle, adding open feed water heaters:
   ii) In a vapor power cycle, adding closed feed water heaters:
   iii) In a vapor power cycle, adding a reheat line in the steam generator:
   Select the best answer from the following choices to complete each statement
   (A) improves the thermal efficiency (B) reduces the heat input into the cycle
   (C) increases moisture content in the turbine (D) decrease the moisture content in turbines
   (E) Both (A) and (B)

3. Consider the flow of moist air in a duct as shown in the following diagram



Select the best choice for the humidity ratio, w_2, at the outlet from the following choices:

(A) $w_2 < w_1$ (B) $w_2 = 1$ (C) $w_2 = w_1$ (D) $w_2 > w_1$
(E) None of the above

4. Consider moist air at 1.0 bar, 35 ^{o}C, and 70% relative humidity. Select the best answer for the dewpoint temperature, in ^{o}C from the following choices:

(A) 10.5 (B) 24.6 (C) 28.6 (D) 31.1 (E) 38.3

5. For a sphere having constant thermal conductivity, k, with no internal heat generation, the heat diffusion equation for a steady state, one dimensional heat conduction process in the radial direction can be presented as

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dT}{dr}\right)=0$$

The two r^2 in the above equation cancel each other and the equation can be presented as

$$d^2T/dr^2 = 0$$

(A) True (B) False

6. Select the best answer from the following choices that describes Bi (Biot) number

(A) Bi # is the ratio of internal thermal resistance/external thermal resistance
(B) Bi # is the ratio of external thermal resistance /internal thermal resistance
(C) Bi # gives the order of magnitude for the ratio of internal temperature change /external temperature change
(D) Both (A) and (C)
(E) None of the above

Students used their I-clicker devices to provided answers to the questions and get immediate feedback on whether their answer was correct. Then the instructor provided additional explanation and responded to students' questions to clarify any misunderstanding. when

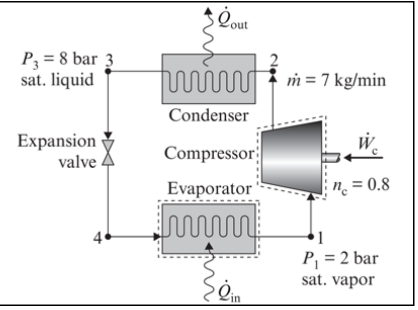
Unfortunately, during the COVID pandemic period (Spring 2020 to the end of Summer 2021) and on-line instruction, the application of active learning concept and appropriate use of electronic pooling devices was less practical. Therefore, the effectiveness of active learning was vastly reduced during that period.

Right after COVID pandemic period (Fall 2021) the authors observed a noticeable poor exam performance. Students had more difficulty to start solution steps in solving problems and were weak in solving analytical problem. Therefor, instead of using true/false, multiple-choice question for active learning, it was decided that the most effective approach involves aligning the learning activity with homework or exam questions as they are often used as the primary tools to access student learning and to assign class grades. The pop quizzes, mostly require students to show solution steps in detail rather than responding to true/false or multiple-choice questions. Showing the process and explaining the steps is more effective than guessing the best response out of a list.

In one of the authors' classes, the closing active learning problems are not graded. Students are encouraged to work in teams. The problem is often broken into parts and the instructor walks the room answering questions as well as checking the answers for correctness. Students want to know if they have solved part (a) correctly before proceeding to part (b) and beyond. The instructor has found that positive feedback with a flare of celebration is effective at motivating students. Students like it when they are correct and like it when fellow students are correct. Instructor will use phrases like "Good job", "well done", "excellent work", "correct!", "bingo", etc. If an answer is wrong, instructor may say "keep working on it", or "you solved the problem assuming XXX but is that the case here? isn't it YYYY". Hints are freely given. Telling a student straightforwardly they are "wrong" without guidance isn't helpful. If a student has a wrong answer, the instructor may encourage a student to make a new friend in the class, since a neighbor may have solved the part correctly. In the majority of cases, students want to be helpful and want to be helped when they are stuck. The class becomes alive as students work together, talking within the room. A surprising result is that a number of students will continue to work on the problem after the end of the class. As the semester proceeds and students become more comfortable with ending the class with a work-it-out problem, they also feel empowered to leave class early (maybe to get to a restroom, get to a back-to-back class across campus, leave for family reason, etc.) and they can do this without the ire of the instructor. In traditional lecture, the instructor may be trying to make one last important point and having students leave early can be distracting. Experience shows that very few students leave early and if they leave early they often want to explain to the instructor that it is for a good reason. Most students will work on the problem until the official end of class and some beyond. If the problem is long, the instructor encourages students to finish it before next class. The problems chosen fare like homework and exam problems. Student realize the end of class problems become "fair game" for exam problems. The instructor will sometimes reveal these problems all at once in the beginning of the semester or may only present the individual problems during the class meeting time. Either approach is fine. Presenting them as a group at the beginning of the semester allows eager students to work on them before lecture. Although many students say they want the problems early for this reason, in practice it is more common for students to not have worked the problems before class. They often are so busy that they don't solve problems before class. More often students want the problems so they can miss a class yet still know what problems were covered. Some semesters the instructor has only revealed the problems in lecture and did not post them for students who missed the class. The reason for this is to encourage class attendance, yet this often makes enemies of a few students who believe the instructor is being lazy. Currently the strategy is to make the problems available at the beginning of the semester since class attendance is voluntary and this tends to minimize student complaints.

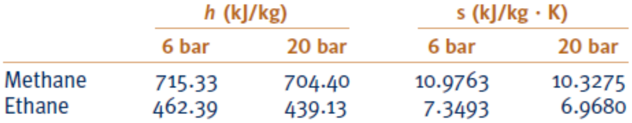
During the 2022-23 academic year, some classes had mandatory attendance using the "University's "Instructor Initiated Drop policy". This policy allowed the instructor to drop any student who exceeded either the absence (4 times) or missed assignment (3 sets) limits, stated in the course syllabus.[8] In this case quizzes were used for active learning events. To provide an incentive for students to participate in class activities, the quizzes had a weight of 2% bonus points, counted for evaluating the final grades. Some quizzes were short requiring only 5 to 10 minutes of class time for students to show their solution steps, close to the end of the class period. Students' solutions were collected, then the instructor immediately went through the solution and answered student's questions. For longer problems requiring 10 to 20 minutes of class time for students to solve the problem, the quiz was given near the end of class, allowing sufficient time for students to submit their solution and leave the class. In this case, the solution to the quiz was posted on-line promptly after the class and it was briefly discussed at the beginning of the following class. For most quizzes, students were free to brain storm with their neighbors to solve problems or work individually, if they wished. The instructor initiated drop policy" improved class attendance and students completing their homework assignments. In class sizes of over 50 students, no more than two students were dropped due to the enforcement of the policy. All quizzes were graded after the class period. Most problems used for quizzes were from of problems in textbooks [9,10,11] required for thermodynamics and heat transfer courses, modified to ask students to present detailed solutions. The followings are a few examples:

1. Consider a liquid entering a pump of vapor power cycle at a pressure of p_3 and exiting at a higher pressure, p_4. Assuming steady state, adiabatic process, with no internal irreversibility in the pump, derive an equation for power required by the pump, per unit mass of fluid in terms of v_3, p_3, and p_4. Start with modifying the general equations for mass balance, energy balance, and entropy balance, as applied to this problem. Kinetic and potential energies of fluid flow are negligible in this problem.
2. A vapor-compression refrigeration cycle operates at steady state with Refrigerant 134a as the working fluid. Saturated vapor enters the compressor at 2 bar, and saturated liquid exits the condenser at 8 bar. The isentropic compressor efficiency is 80%. The mass flow rate of refrigerant is 7 kg/min.

a. Show the processes involved in this cycle on a T-s diagram and determine: b. the compressor power, in kW. c. the refrigeration capacity, in tons. d. the coefficient of performance	

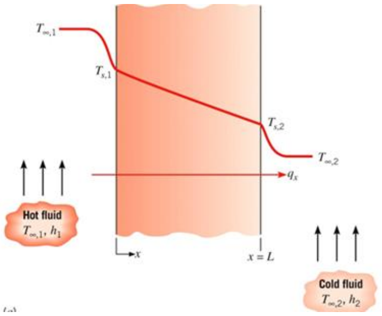
3. The analysis on a mass basis of an ideal gas mixture at 30 ºF, 15 $\text{lb}_f/\text{in.}^2$ is 55% CO_2, 30% CO, and 15% O_2. Determine:
   (a) the analysis in terms of mole fractions.
   (b) the apparent molecular weight of the mixture.
   (c) the partial pressure of each component, in $\text{lb}_f/\text{in.}^2$
   (d) the volume occupied by 10 lb of the mixture, in ft^3.

4. Natural gas having a molar analysis of 60% methane (CH_4) and 40% ethane (C_2H_6) enters a compressor at 340 K, 6 bar and is compressed isothermally without internal irreversibility to 20 bar. The compressor operates at steady state, and kinetic and potential energy effects are negligible. Assuming ideal gas behavior, determine for the compressor the work and heat transfer, each in kJ per kmol of mixture flowing The following properties are known for methane and ethane at 340 K:

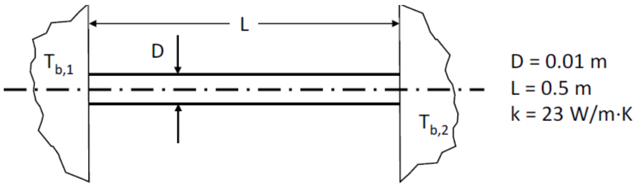


	h (kJ/kg)		s (kJ/kg · K)	
	6 bar	20 bar	6 bar	20 bar
Methane	715.33	704.40	10.9763	10.3275
Ethane	462.39	439.13	7.3493	6.9680

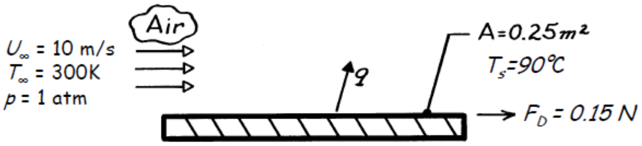
5. If $T_{s,1}$ and $T_{s,2}$ are unknown, Derive equations for evaluating overall thermal resistances, $T_{s,1}$ and $T_{s,2}$, the rate of heat transfer, in terms of $T_{\infty 1}$, $T_{\infty 2}$, h_1, h_2, and k



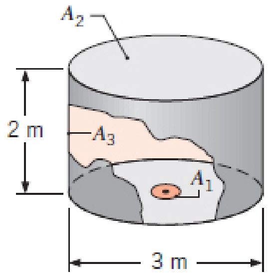
6. Two thick walls are separated by a vacuum gap of thickness L. A cylinder of diameter D runs between the walls. All surfaces are highly polished (their emissivity is small). The walls are at temperatures $T_{b,1}$ and $T_{b,2}$ at locations far from the cylinder.
   (a) Draw the thermal resistance network.
   (b) Derive an expression for the shape factor, S, associated with conduction between $T_{b,1}$ and $T_{b,2}$.
   (c) Determine the value of the shape factor for D = 0.01 m, L = 0.5 m, and k = 23 W/m·K.



7. Atmospheric air is in parallel flow (u_∞ = 10 m/s, T_∞ = 15°C) over a flat heater surface that is to be maintained at a temperature of 90°C. The heater surface area is 0.25 m^2, and the airflow is known to induce a drag force of 0.15 N on the heater. What is the electrical power needed to maintain the prescribed surface temperature?



8. Consider the arrangement of the three black surfaces shown, where A_1 is small compared to A_2 or A_3.
   Determine the value of F_{13}. Calculate the net radiation heat transfer rate from A_1 to A_3 if $A_1 = 0.05$ m^2, $T_1 = 1000$ K, and $T_3 = 500$ K.



A comparison of exam performance by students enrolled in Thermodynamics-II in spring semesters of 2021, 2022, 2023 is presented in Table 1. Because of the implementation of the instructor initiated drop policy and the active learning quizzes, Table 1 shows that the average score in exams were found to be approximately 10 to 20% higher in spring semesters 2022 and 2023 as compared to those students who took the same courses in spring 2021.

Table 1. Comparison of exam performance by students enrolled in Thermodynamics-II in spring semesters of 2021, 2022, 2023

Exams	Semester	# of exams	< 60	60-69	70-79	80-89	> 90	Ave	Std-Dv
Exam 1	Spring 21	42	57%	12%	14%	12%	5%	54.43	22.6
	Spring 22	86	35%	21%	14%	8%	22%	68.90	20.61
	Spring 23	58	36%	16%	14%	16%	19%	67.68	24.37
Exam 2	Spring 21	38	79%	3%	3%	8%	8%	52.05	21.00
	Spring 22	85	26%	16%	19%	13%	26%	71.44	22.64
	Spring 23	57	32%	12%	19%	11%	26%	70.18	23.84
Exam 3	Spring 21	34	47%	24%	12%	9%	9%	58.59	22.51
	Spring 22	75	15%	16%	17%	19%	33%	75.30	19.40
	Spring 23	50	10%	8%	24%	34%	24%	80.00	16.31
Final Ex	Spring 21	29	55%	17%	7%	17%	3%	55.62	26.46
	Spring 22	72	43%	14%	11%	14%	18%	66.97	21.41
	Spring 23	45	31%	27%	27%	9%	7%	65.78	16.91

Table 1 exhibits a declining trend in number of students taking exams as the semester progressed each year. There were several factors contributing to this fact. One reason was that each semester the lowest grade of the midterm exams was replaced with the average score of the rest of the exams. The other factor was that some students dropped the course, because either they could not keep up with the course requirements, or were not performing well in previous exams. One more reason was that some students were failing the course, but they could not drop the course, because of the university policy of exceeding the withdraw limit during college career, thus they were not taking the remaining exams during the semester.

Table 2 compares the grade distribution for thermodynamics-II course offered in spring semesters of 2021, 2022, 2023. The lowest passing rate of 56% was in spring 2021, when the course was offered during the COVID pandemic. The passing rate improved during spring semesters 2022 and 2023, when the active learning concept described in this paper was implemented. The passing rate was the highest (67%), when the Instructor Initiated policy was implemented along with the classroom active learning events. The percentage of D and F grades were the lowest in spring 2023 (12%) as compared to those in spring 2021 (39%) and in spring 2022 (27%). But, the percentage of W grades was the highest in 2023 (22%), due to the implementation of the Instructor Initiated policy. In this case, out of 12 students who received a grade W, only one was dropped by the instructor. The possible cause for the remaining students withdrawing from the course was because they did not have sufficient time to attend the class or complete their assignments.

Table 2. Comparison of grade distributions in Thermodynamics-II course in spring semesters of 2021, 2022, 2023

Semester	Grade Distribution							
	A	B	C	D	F	W	ABC	DWF
Spring 21	19%	9%	28%	2%	33%	9%	56%	44%
Spring 22	30%	15%	18%	11%	16%	9%	63%	37%
Spring 23	24%	18%	25%	6%	6%	22%	67%	33%

Summary and Conclusions

Active learning is effective at promoting student learning, yet requiring students come to class having completed pre-class activities if challenging and found often student dissatisfaction as they feel the instructor is being lazy by not lecturing. When lectures are provided, student attention dwindles especially near the end of class. So, the authors have settled on end of class activities that promote active learning. In some cases, problems are presented in a pop quiz format, where it is most effective to require students to show the process and steps versus placing emphasis on the final numeric answer. The challenge with pop quizzes is that student often resent being graded on material which may have only recently been presented, not allowing them sufficient time to review lecture materials before being graded. A significant advantage of having graded pop quizzes is increased class attendance.

Different strategies have been tried on how and when to share correct answers. It has been found that sharing the correct answer(s) when the problem is initially presented is least effective since it often promotes a shallow approach to problem solving. It is recommended that the following lecture commences with a review of correct answers. The authors have observed that ending lectures with active learning activity has improved learning, and increased opportunities to emphasize the important points from the lecture. The last 10 minutes of class represent 20% of the contact time in a 50 min lecture and 13% of a 75 min lecture, it is concluded that closing with active learning activity increases student attentiveness in the range of 13 to 20 percent. Exam scores were found to be 10% to 20 % higher compared to previous semesters when active learning activities didn’t conclude lectures.

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