Active Learning in Thermodynamics by Leaving the Front of the Classroom

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Abstract

The fundamental premise of active learning is that students learn better when they both think and do. There are numerous strategies to promote active learning in a traditional engineering class. This paper summarizes one strategy used in a thermodynamics class taught in an amphitheater classroom designed for lecturing to over one hundred students. The instructor poses a question then leaves the front of the room and roams the class. Moving among students provides opportunities to engage students on a more personal level and often leads to student questions and increased engagement. Student feedback is positive that they value the time spent solving problems during class.

Keywords

Active learning, thermodynamics.

Introduction

Although active learning methods have been shown to improve student learning, the adoption in engineering isn't as widespread as it could be. Barriers to the adoption of active learning methods include lack of faculty time needed to develop new content, and lack of familiarity with active-learning techniques[1-3]. A key in active learning is to give the students something to do while in the classroom[2]. Activities include answering a question, sketching a diagram, solving a problem, deriving a formula, critiquing a design, etc. Students can work individually, in pairs or in groups, and they have a limited amount of time. It appears that effective active learning in the classroom should be brief and guided. When learners have sufficient prior knowledge, less instructor guidance is needed; however, active learning should not be misunderstood as promoting the lack of instructor guidance[4]. Especially for lower-level engineering classes, students should not be left to embrace misconceptions for long periods of time. A balance is needed between challenging the learner with meaningful tasks while clarifying correct solutions versus common misconceptions. Meaningful learning is that which affects long-term memory that guides conceptualizations and cognitive actions for many years. The instructor is key to creating a learning classroom environments and although the same pedagogical approach and instructional tools are used, significant variations in student learning can result for the same class[5]. Variations in classroom practices and the relative emphasis on student sense-making versus answer-making is key to improving student learning.

Active Learning

Active learning techniques have been used in an engineering course which is typically taught three days per week during 50 minute sessions. In the past, the instructor has emphasized classroom demonstrations, quizzing, conceptual questions, quantitative problems, personal response systems, and peer instruction. Various techniques discussed in the engineering education literature have been adopted, modified, and some abandoned based on student feedback and the instructor's assessment on student learning. Some strategies require more instructor effort to implement. Some have been received negative student feedback. Some appear not to have the desired impact on student learning. What appears the most effective is for the instructor to pose a wide range of questions, both conceptual and quantitative. Students are given sufficient time to answer the question. Some questions are answered promptly by the instructor yet it is more impactful if questions are answered by students. I-clickers have been used to collect the responses from all of the students. This has the advantage of collecting and assessing the responses for many more students that is feasible if done by a show of hands or asking particular students to share their responses. The possible disadvantages for electronic response systems include the lack of focus and attention given by some students. It has been repeatedly observed that not all students pay attention to the discussion or material during a lecture.

Electronic Pooling

Electronic pooling (iClicker) has been used to promote active learning in large classes. The primary benefit from using an iClicker system is that the response from many students can be collected and assessed very quickly. For example, in a thermodynamics class the following multiple-choice questions were posed:

> Q1: Under what conditions can you assume an ideal gas model for a gaseous substance? Select the best answer from the following choices: (A) $T_R \approx 0$, (B)$T_R \approx 1$; (C) $P_R \approx 0$; (D) $P_R \approx 1$; (E) $Z = 0$
>
> Q2: The change in internal energy of a closed system undergoing any process is: (A) ≤ 0 , (B) ≥ 0 , (C) ≥ 0 but ≤ 1 , (D) ≥ 1, (E) both A and B
>
> Q3: The change in the entropy of a closed system undergoing any process is: (A) ≤ 0 , (B) ≥ 0 , (C) ≥ 0 but ≤ 1 , (D) ≥ 1, (E) both A and B

The student responses are shown in Figure 1. For the first question, the best response is (C) and 14 students (29% of the responses) selected the best response. For this question, the most popular response is (D). After displaying the results, the instructor then spends class time explaining why (C) is the best response while other responses may have some elements which appear to be correct, yet aren't the best response. For the second question, 53% of the class selected the best answer. For the third question, only 7% selected the best answer, and the instructor was able to address the difference between the "change in the entropy" and entropy generation. If the question has read "The entropy generation of a closed system undergoing any process is", then (B) would have been the best answer.

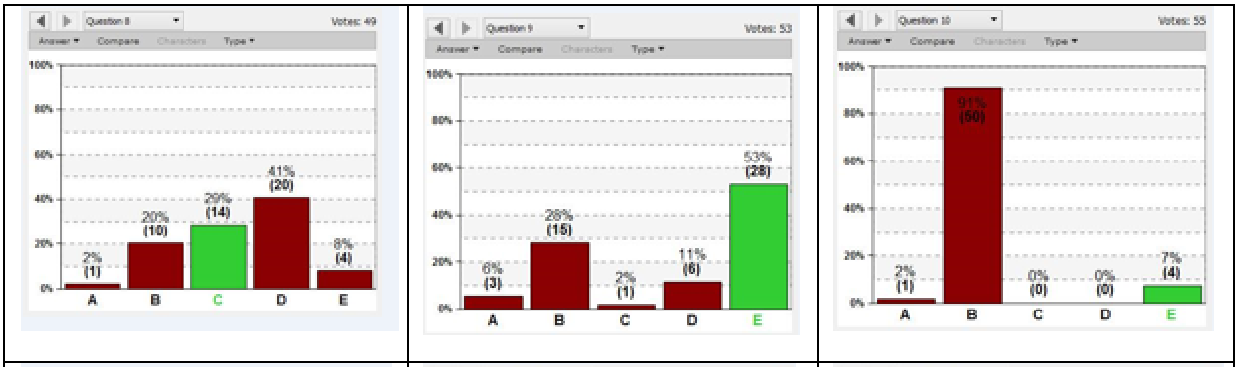

Figure 1. Student responses with correct answer shown in green.

Both authors have used classroom response system (iClickers), and have observed many benefits and improvement in student attentiveness. The perceived downside is that some students display a lackadaisical attitude and simply guess for the best response.

Leaving the Front of the Room

One way to promote an active learning classroom is for the instructor to pose a question and then leave the front of the room. The instructor gives students sufficient time to work on the question and moves throughout the classroom to engage students. It has been found practical to leave the front no more than about two times during a 50-minute lecture. The instructor has had to learn to be quiet especially when students first start working on the problem. This is abnormal and can be uncomfortable. The time it takes for the average student to answer the question is often longer that what the instructor expects. When the instructor can circle the room, especially visiting students sitting in the back of the class. It has been found that the back of the room is where the majority of off-task activities occur. Students choose to sit in the back to avoid observation of off-task activities. The instructor often asks to see the work of students and will give hints to help move students toward the solution.

It has been observed that regardless of the preparation, dedication, excitement or enthusiasm of the instructor some student chose to attend the class with little or no intention of participating in the class. They wish to observe and not engage. These students can be frustrating for the instructor since they ignore the request to work on a problem. It has been found that 3 to 8 minutes is required to allow sufficient time to work on a problem. If the problem is simpler, less time is required and the instructor need not leave the front of the room. If the problem is too complex, then too much class time is devoted to the task and students can become disinterested in further effort. Often the instructor tells the class they will continue after 5 or 10 students correctly answer the question. The instructor will say something like “One correct” and “Two correct” until the number is achieved and the instructor moves to the front of the room. The instructor often asks for a volunteer to explain the solution for the benefit of the class. It is important that the solution be explained, especially for the benefit of those who were unable to solve the problem. Attentiveness is enhanced during and promptly after one of these problems. The instructor often gets more follow-up questions from the class.

Student Feedback

In the Fall 2016 class of ME 4293 Thermodynamics II, the class had about 110 students at the start of the semester and about 100 students in about the 12th week of a 16 week semester. A survey was conducted a total of N=78 students participated. The survey was conducted using paper in the last 15 minutes of a class. The survey was purposefully brief. In addition, a comment section was provided to the students. The first group of five questions focused on what students should do to do well in the class. The results are summarized in Table 1.

Table 1. Results of the survey “In order to do well in this class, students should …”
1= strongly disagree, 2 = disagree, 3= neutral, 4 = agree, 5 = strongly agree

Q	Statement	Ave	1	2	3	4	5
1	do homework	4.9	0%	1%	0%	9%	90%
2	attend lectures	4.6	0%	1%	5%	28%	65%
3	watch recorded lectures	4.4	0%	3%	13%	31%	54%
4	read the textbook	3.8	0%	8%	23%	47%	22%
5	study with other students	3.8	0%	12%	31%	23%	35%

Students agreed that students should do the homework. This confirms that students learn both in and out of class. Regardless of how active learning is promoted in the classroom, students still need to learn outside of the classroom. The response confirms that an active learning classroom encourages learning but is not sufficient for all of the learning required to do well in a class.

Students also agreed that attending lectures was beneficial for this class. Attendance was not mandatory nor recorded during the semester. As a result, attendance was about 70%, so that about a third of the students were missing each class. Regardless of how innovative and effect the classroom meeting time can be made, students may not attend.

The third question shows that students reviewed the recorded lectures. The lectures were screencasts and posted to YouTube. Student feedback has been positive since they can review specific lectures. A downside to screencast lectures is that they may promote absenteeism.

Reading the textbook and studying with a group of students is beneficial, so students largely agree that these activities promote learning. It appears that about 1/3rd of the class strongly agree that studying with other students is recommended, with about 1/3rd remaining neutral on the issue. Over 10% disagree with studying with other students, probably because their schedules make it impractical or that they never found a group with which to study. Inside the classroom, about 1/3 of the students sit by themselves so they work in isolation on problems in the classroom.

The next set of questions focused on what should be done during the 50 minutes of class meeting time. The first two responses show the importance of problem solving. Both the instructor and students should solve more problems. Questions 8-10 show the importance of short conceptual questions and he subsequent answers to these questions. More questions are encouraged. Question 11 shows there is a lack of consensus on students working in groups during the 50-minute class meeting time.

The authors have used i-clickers yet one author did not use them in the Fall 2016 semester. The benefit is the responses from everyone with clickers can be collected and displayed very quickly. Questions 12-14 are consistent with student feedback from previous semesters. There is no clear consensus if clicker questions should be graded or not. Some students feel strongly that they should not be penalized for incorrect responses while they are struggling to learn the material. Experience shows that if students are not graded, then participation declines and many students become cavalier. When questions are posed during the class, some become less engaged knowing the instructor will eventually answer the question that has been posed. Coupled with the modest additional expense students incur to acquire the clickers, it was decided to continue the practice of posing questions during lectures without the use of electronic clickers. Instead, the instructor purposes to leave the front of the room and review student work on the task.

Table 2. Results of the survey "During the 50 minutes class meeting time…"
1= strongly disagree, 2 = disagree, 3= neutral, 4 = agree, 5 = strongly agree

Q	**Statement**	**Ave**	**1**	**2**	**3**	**4**	**5**
6	students should solve more problems	3.7	0%	5%	38%	38%	18%
7	instructor should solve more problems	3.6	0%	8%	37%	41%	14%
8	instructor should ask more questions	3.6	0%	5%	42%	38%	14%
9	instructors should require students to answer questions	3.5	1%	14%	33%	37%	14%

10	students should listen to and learn from fellow students	3.3	8%	12%	37%	35%	9%
11	students should solve problems in groups of students	2.9	5%	27%	46%	13%	9%
12	If i-clickers are used in the class, the results should be graded	2.7	18%	26%	27%	24%	5%
13	instructor should use i-clickers for quantitative questions	2.6	21%	26%	28%	22%	4%
14	instructor should use i-clickers for class attendance	2.5	27%	26%	26%	14%	8%

Conclusions

Instructors must consider the additional effort required to adopt instructional strategies and the anticipated improvement in student learning. Based on student feedback, it is recommended that instructors adopt the active learning technique of posing conceptual and quantitative questions during classes. Student responses can be collected electronically using a classroom pooling system. It is also recommended that the instructor leave the front of the classroom and observe student work. Roaming the class has been found to promote student engagement. It has been repeatedly observed that some students, especially towards the back of the room, need additional encouragement to participate in the class. Student feedback is positive that having students solve problems and answer short questions does promotes active learning. Student feedback is mixed on the use of an electronic student response system. Some student feedback is negative when results are graded. Overall, the strategy of leaving the front of the room and engaging students is recommended as a way to promote active learning in the classroom.

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