# Active Learning using a Classroom Response System in Thermodynamics

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## Abstract

Because of the limited attention span of students, instructors often seek tools that keep students actively engaged in the classroom. Electronic pooling has been used to promote active learning. Classroom activity results from students being required to respond to a question within a fixed period of time. Responses are tabulated and the distribution of responses are displayed for the class to see. The instructor often leads a discussion on why the correct answer is correct and other answers aren't. This approach has been found to increase student engagement in the classroom. Pooling grades have a modest positive correlation with exam grades. Likewise student feedback is positive in that it improves engagement, attentiveness, and overall learning. Students feedback is that classroom pooling responses should not be factored into the final course grade except possibly as extra credit.

## Background

Classroom electronic response systems are used to pose true/false or multiple choice questions where students answer by selecting a choice on a remote that transmits the response to a central collection system controlled by the instructor [1-4]. Many of these systems are described as "clickers" [1] which is a term used in this paper but a classroom response system refers to a pedagogical method and not to a specific commercial implementation. The instructor poses a questions and the class is given time to answer. The distribution of responses can be displayed and the correct answer selected by the instructor. The system then records the responses for grading purposes. The value of such systems is prompt formative feedback to help students reflect on their learning and performance. The potential drawback is that more class time is devoted to the response system. The instructor must get student to come better prepared to class since less time is available for content coverage [2]. One can adopt a commercial system that typically requires student to purchase a "clicker" or one can adopt a free system like Votapia [3] or QuizIt [4] which may or may not allow grading of responses. There is significant evidence that constant monitoring and assessment of student learning though frequent quizzing improves student engagement and learning [5]. It has been found to encourage students to be active participants in the classroom [6]. The use of classroom response systems allows more class time to be spent on students working on problems hence the students are more active, and less time listening to the instructor lecture. With electronic pooling, more time is spent posing a question, giving time for students to answer question, collecting/displaying the responses, and then discussing why answers are correct/incorrect. The goal is to make the limited classroom time as effective as possible, especially with large numbers of students in the typical theatre-styled classroom. There is a growing understanding that the role of the instructor can shift to be more of a facilitator so that students become more engaged in a cooperative learning structure.

It is recognized that concepts are critical in thermodynamics and poor learning can be traced to persistent student misconceptions [8-9]. Questions have been developed that probe specific concepts such as descriptions of process (e.g., adiabatic or isothermal) or distinguishing between temperature and energy, steady-state versus equilibrium, etc. [10]. Instructors strive to address areas of common misconception and do this repeatedly using multiple quizzing forms to improve learning [11]. A sound understanding of where student struggle is considered key to improving student success [12]. There is increased consideration of thermodynamics pedagogy based on educational studies of teaching methods that work [13].

**Method**

An example of the use of a classroom response system is shown in Figure 1. This example is based on one of the earliest lectures in the semester. A review of pressure is conducted with emphasis on atmospheric, absolute and gauge pressure. Pressure is a prerequisite topic and many instructors who teach thermodynamics assume students have already mastered these concepts. After an extensive review of the concepts, the instructor asks about the typical air pressure in the vehicles that students drive. Students often engage in the classroom discussion sharing different pressure ranges for passenger tires, truck tires, and sport tires. The typical units used by students in the discussion is psi, or pounds per square inch. The typical atmospheric pressure is reported to be 14.7 psi which is a familiar number for many students. The instructor asks students to round off to two significant digits, hence students report atmospheric pressure to be 15 psi. The instructor then moves to a new screen and presents a question about the absolute pressure in a tire that has 30 psi gauge pressure. This is posed in a classroom response or "clicker" question. If the air pressure is 30 psi gauge, what is it in psi absolute? The multiple choice responses given are: (a) 15 psia, (b) 30 psia, or (c) 45 psia. Students often have 30 seconds to respond during which time the instructor is completely silent and the students can talk with other students. The pooling ends and a results chart is displayed on the screen. In Figure 1, one finds that 22 students (or 29% of the class) selected (a), 19 selected (b), 35 selected (c) and one selected (d).

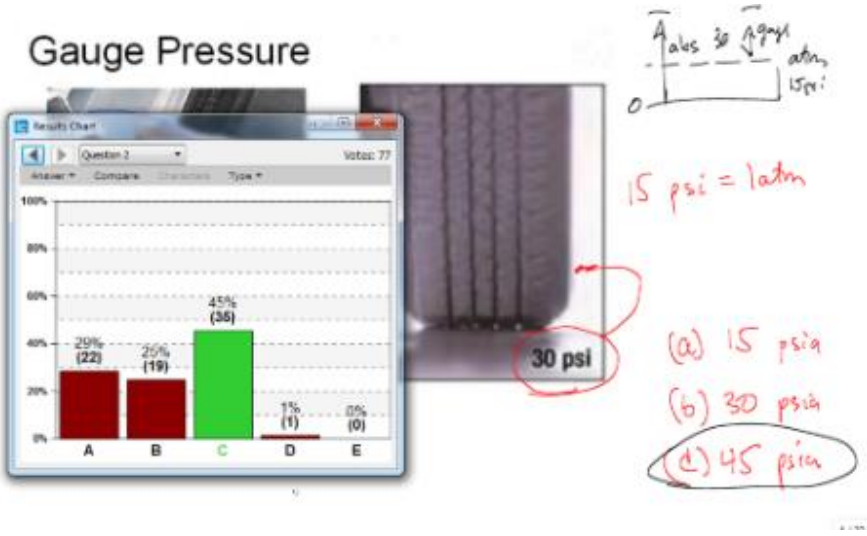


**Figure 1. Typical use of clickers to assess student learning in the classroom. Question about the absolute pressure of the air in a passenger tire.**

This is an example of a surprising observation which is revealed by classroom pooling: many students often don't understand the most basic points in a lecture. The instructor was initially surprised by the number of incorrect answers. This question was not intended to be tricky, but just the opposite. It was designed to be an easy "warm-up". The instructor often asks this question on the second day of the semester. It was intended to be an encouraging question which should have a very high number of correct responses. Yet results show a significant part of the class (over 50%) answer incorrectly. The high number of incorrect responses to seemingly simple questions continues to surprise the instructor. Throughout the semester, it is extremely rare to get 100% correct response from the class.

Figure 2 provides another example of a question later in the semester. The second law of thermodynamics has been introduced and each term described. The students have used the second law for closed systems for the past week. The closed system equation is most often used for a process, from initial state 1 to final state 2. The class now develops the second law for an open system which is written on a rate basis. This question highlights the fact that students may struggle with something as basic as the

units for each term. Students are asked to identify the units of the entropy generation term with the possible responses being: (a) kW, (b) kW/K, (c) kW/(kgK), (d) kJ/(kgK). This question offers the opportunity to stress the usefulness of units to check ones work.

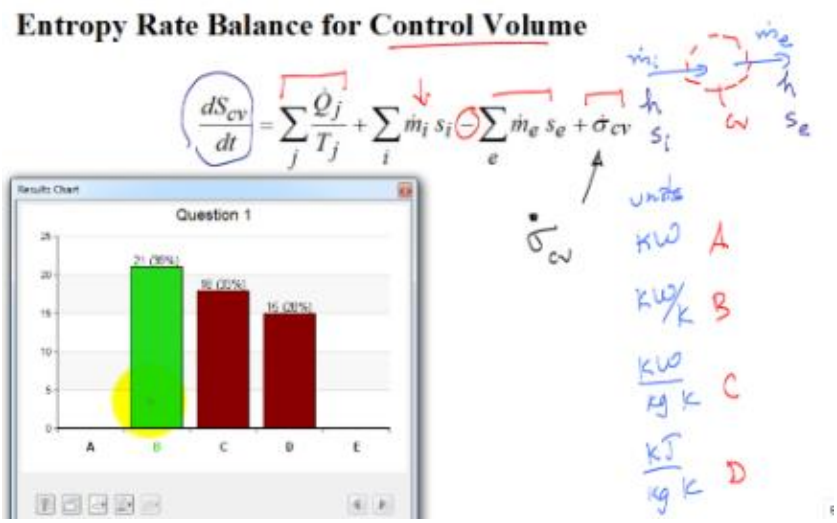


**Figure 2. Question about the SI units expected for the entropy generation term in the second law of thermodynamics for an open system.**

**Student Learning**

The clickers have been used in four engineering thermodynamics classes over a one year period. From the perspective of the instructor, it is surprising the number of incorrect responses received. It has highlighted that many students appear to be "lost" or "disengaged" during lectures. The clicker score was set to 3% of the overall final grade in the class, hence it was of low overall weight. The exam scores accounts for 90% of the overall final grade. The clicker grades versus exam grades are compared in Figure 3.

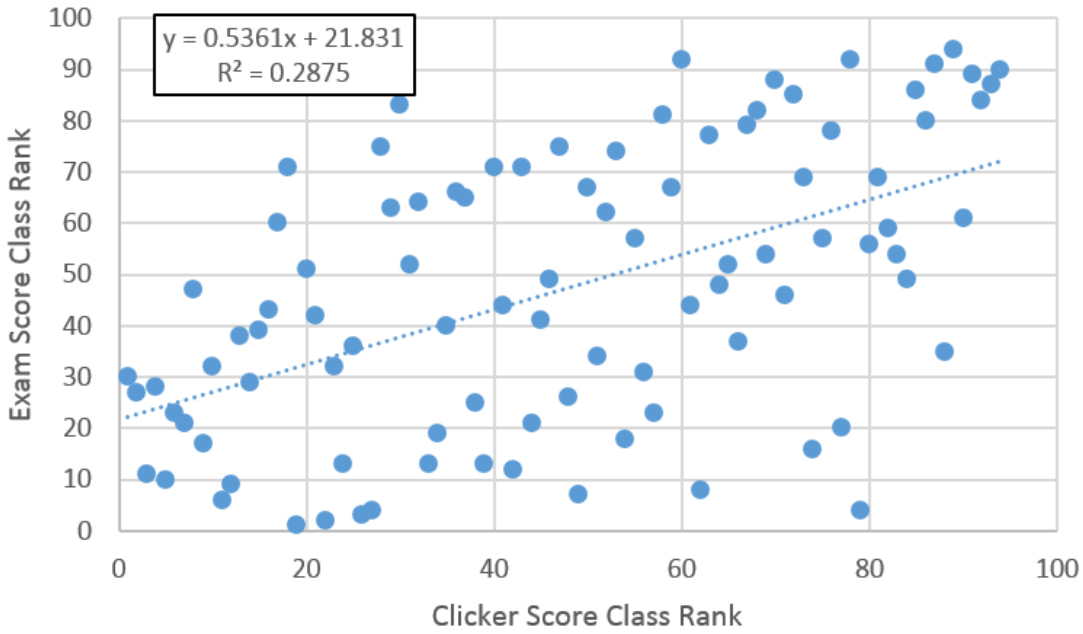


Figure 3 **Clicker Score versus Exam Score for N=95 students in Fall 2015 classes.**

There is a discernable trend that those who earn high clicker scores also earn high exam scores. A few students chose not to participate in clickers so 7 students are removed from the total of 102. A few of the students who earned high clicker scores did poorly on exams, which is disheartening. Upon investigation, it was found that clicker questions need to be offered consistently throughout the semester. Some days there were few clicker questions. This difference can explain some of the trends since a student may miss a lecture where there were more questions which would reduce the clicker score for the semester.

**Student Feedback**

At the end of semester, the students were asked to participate in a survey concerning the use of classroom questions and electronic pooling. The results are summarized in Table 1. The questions probe specific aspects of the pedagogical intent of classroom pooling, especially promote student engagement and active learning in the classroom. So it is encouraging to see that students agree that clicker questions promote engagement in the classroom. Students are also attend lectures more frequently. However, clickers don't help students come to lectures more prepared. Follow up work is planned to see what can be more effective at getting students more prepared for each lecture. It was encouraging to see students agree they are more attentive during lectures and learn more during lectures when clickers are used. Part of learning is seeing that they understand the correct answer to a question. Prompt feedback is the greatest strength of the use of clickers and students had the strongest response to the "feedback" survey question. There continues to be differences of opinion about the use of conceptual versus mathematical questions. If students are asked to perform numerical calculations, this takes more class time so the emphasis has been on conceptual questions. This is also supported by the observation that the concepts in thermodynamics are especially challenging for students. Students often have problems with concepts, not the math. Student feedback is that pooling questions should not be graded and contribute to the overall final grade in the course. At present, the instructor believes they must be graded and counted otherwise more students will not participate. The percentage was 3% in the Fall 2015, yet about 7% of the class never participated in clickers. They probably didn't believe it was worth the cost to acquire a clicker and the effort to bring it to class regularly. The cost should not be a factor since students can check-out a

clicker from the library for the semester, and other prerequisite courses in the engineering program currently require students to have clickers. The primary objection appears to be the inconvenience of bringing the equipment to the class. Lastly, student believe clickers should continue to be used. The last question in the survey was one of the most important in assessing whether to continue the use of clickers. In many ways, the instructor must do more work to use clickers in the classroom. The must bring some equipment, set-up the equipment, prepare question, and often upload clicker grades. If the student feedback would have been more negative on the last survey question, the instructor would discontinue the use of clickers.

**Table 1. Summary of student response to end-of-semester questionnaire (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree).**

| | **Spr2015 N=67** | **Fall2015 N=72** |
|---|---|---|
| You are more **engaged** in the classroom, when clickers are used. | 4.5 | 4.3 |
| You come to lectures more **frequently**, when clickers are used. | 4.2 | 4.2 |
| You come to lectures more **prepared**, when clickers are used. | 3.6 | 3.4 |
| You are more **attentive** during lectures, when clickers are used. | 4.3 | 4.2 |
| You **learn** more during lectures, when clickers are used. | 4.2 | 4.0 |
| You prefer **conceptual** questions, instead of quantitative questions. | 3.6 | 3.8 |
| After feedback, you **understand** why your answer was either correct or incorrect. | 4.5 | 4.6 |
| Clicker questions should be **graded.** | 3.7 | 3.6 |
| The instructor should use clickers **next semester.** | 4.4 | 4.2 |

Student comments also reinforce some of the numerical survey responses. Concerning conceptual questions, students wrote:

*"Conceptual are fine, avoid the mathematical/computational questions."*

*"You lead up to the question, ask a critical thinking question, and afterward give a thorough explanation."*

*"Don't prefer conceptual questions because I'm usually wrong, but is a good way to make sure students understand important concepts."*

Concerning engagement and attentiveness, students wrote:

*"Keeps you on your toes and lets you know where you need to improve in the material."*

*"Clickers are a great way to maintain the class engaged and attentive."*

*"I don't like to use Clicker. But it helps to focus more"*

*"They wake me up during the middle of the lecture".*

Concerning preparation for class, one student commented:

*"Designate clicker quizzes to incentivize students to prepare for class"*

Concerning grading and the cost of clickers, many students commented that the cost was high and they don't like it that they were being graded. Regardless of the low weight given and the high percentage of questions dropped, some students consistently complain on these points.

*"Clickers should be used to help understand the concepts but not punish if your answer is wrong since you are learning from your mistakes."*

*"Personally I don't think attendance should be graded."*

**Conclusions**

The use of clickers appears to have a positive impact on student learning. The instructor can ask questions and electronically collect the responses from all of the students. The use of a collection system should not restrict an instructor to a particular style of classroom interaction as long as the instructor takes time to ask questions, collect student responses, and then discuss the answers. Feedback from students indicate they (1) dislike use of equipment primarily for class attendance, (2) dislike questions which require significant numerical work, (3) dislike complicated or "overly tricky" questions, and (4) dislike it when there is insufficient feedback for them to understand the correct answer promptly after they have answered the question. Suggestions for adoption include (1) use short questions that are readily understood by students (2) offer true/false or multiple choice questions with simply worded and distinct answers (3) for numerical responses make the answers significantly distinct (e.g., 10, 50, 100, 500 or 1000), and (4) allow sufficient class time for students to answer the question, and (5) allow sufficient time to explain why answers are either correct or incorrect. It is helpful to explain why a popular incorrect answer could have been correct if the problem wording was changed, or why it was temptingly incorrect. Overall, feedback from students is that the technology for collecting student responses does promote interaction between students and the instructor and students recommend clickers continue to be use in the class.

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