Implementing a Team Exam in Thermodynamics

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I. Introduction

An increased emphasis on the importance of developing team skills within the undergraduate engineering curriculum has taken place over the past several years, and has culminated in its inclusion as one of the ABET 2000 outcomes[1]. While in the past this portion of the curriculum was primarily regulated to design project teams, typically occurring in the final year of instruction, teaming exercises are currently being implemented in a number of courses throughout the curriculum[2,3]. On the surface, it may seem that it is difficult, if not impossible, to incorporate meaningful teaming experiences into certain classes; thermodynamics being one. However, in order for our students to develop the teaming skills they will need upon entering the engineering workforce, it is imperative that instructors implement teaming activities throughout the entire curriculum. One means of doing this is with team exams.

This paper describes my experiences with implementing a team exam in a first course in thermodynamics. In actuality, the team exam has been used in two courses, one of which is taught to mechanical engineering majors the other of which is taught to non-mechanical engineering majors, primarily from the civil, environmental and electrical engineering programs. Both courses last ten weeks on a quarter system and utilize the same textbook; the difference being that the mechanical engineering course is four credits, while the non-mechanical engineering course is three credits. Thus, one course does cover more material than the other. However, the material contained in the team exam is the same in both cases, and therefore, for the purposes of this paper, there is no difference between the two courses. I have taught this course six times, to a total of 192 students, prior to the use of a team exam. Since implementing the team exam in the fall quarter of 1995, the course has been taught seven times, to a total 394 students. In all cases, there have been three hour exams given during the quarter and also a mandatory comprehensive final exam. In addition to the team exam, students are required to work on homework teams, which complete all of the assigned weekly problems. In some instances, the homework teams were self selected by the students and at other times they were assigned. In all instances, these homework teams consisted of three or four students. No formal teaching of teaming skills is done in the course, however, advice is provided if it is requested by the students.

II. Pre-Exam Activities

Upon deciding to include a team exam in a course, the next most important decision that an instructor has to make is what material will be covered on the exam. Of course, this will also determine when during the course the exam will be given. As mentioned earlier, there are three hour exams in my thermodynamics course, so the question was, which of the hour exams should

be converted into a team exam. There were a number of factors which influenced my decision that it should be the second hour exam.

Before giving serious consideration to implementing a team exam, I noticed that the performance on the second exam in my thermodynamics classes was deteriorating relative to the other two hour exams. This is shown in Figure 1. The material that is covered on this exam consists of determining the thermodynamic properties using one of a variety of methods, including the steam tables, the incompressible substance model, and the ideal gas model, both with and without the assumption of constant specific heats. I had the impression that this breadth of methodologies was leading to the problem with the exam. While the students could master each method for determining the properties, they were not yet fully practiced in choosing the correct method for a particular situation, and therefore lacked the needed confidence to solve the exam problems. Using a team exam for this material would give the students another person with whom to discuss their choice of solution method, and thereby gain the confidence to solve the problem. This, along with the fact that the material covered in this exam was needed for the remaining hour exam and the final exam, made it an appropriate choice for the team exam. It met with, what I feel, are the two important criterion for team exam material; i) it is of sufficient difficulty, and ii) the student can not successfully complete the course without learning the material.

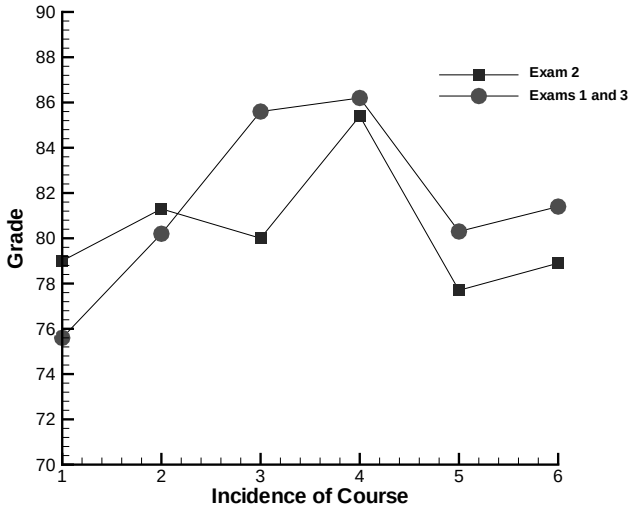


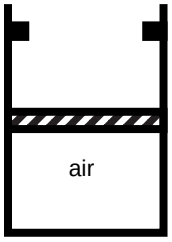
Figure 1: Grades for exams given before implementing the team exam

Upon determining the content of the team exam, the structure of the exam must be established. While it is my usual practice to include some short essay questions on my hour exams, I felt this was not appropriate for the team exam, and therefore have always given only number problems for these exams. The primary reason for this is that the essay questions are rather short, and therefore the exams which contain them typically have five or six different problems/questions. This number of different problems becomes cumbersome when administering the exam, as will be explained later in this paper. Therefore, I have given three number problems on all of my team exams. At least one of these problems is more complex than the others, thus requiring some higher cognitive abilities, and hopefully meaningful discussion between the team partners. An example of such a problem is as follows:

2. (30 pts) A piston-cylinder device, with a set of stops at the top, initially contains 3 kg of air at 200 kPa and 17 °C. Heat is transferred to the air, and the piston rises until it hits the stops, at which point the volume is twice the initial volume. More heat is transferred until the pressure inside the cylinder also doubles.

a) Assuming that the air behaves as an ideal gas, determine the work done, and the amount of heat transfer for this process, both in kJ. Show the process on a P-V diagram.

b) Using the generalized compressibility chart determine the initial volume of the system.



To solve this problem, the students not only have to determine the properties at the three states, they also must determine the processes which occur. During a first course in thermodynamics this is a challenge for the students, and therefore it may result in some collaborative learning during the exam, as they struggle to determine the solution.

The next step in the process is to divide the students into teams for the exam. I have used only teams of two, with an occasional team of three when necessary, because of there being an odd number of students in the class. (While I did not receive any negative feedback from the few teams of three that I have had, I have remained with the two student teams.) Establishing the team assignments is a two step process. An initial set of team assignments are made randomly, using student ID numbers. These initial team assignments may then be adjusted for one of two reasons. The first, and most prevalent reason, is to separate any students who were assigned to take the exam with one of their homework team members. The students in these pairings are reassigned primarily to ensure that no team is given an unfair advantage by having had the opportunity of working together for four to five weeks prior to the exam. This also minimizes the chance that one team member will intentionally not study a portion of the material because they know their partner understands that material.

The second reason for adjusting the initial team assignments is to eliminate large differences in student abilities as demonstrated by their performance on the first exam. I want to stress that the term **large** in this instance means an A student assigned to work with a D or an F student, again as based on prior performance in the present class. Students in teams such as these will be reassigned to form teams with others closer to their abilities. While this may be viewed as team fixing, I have taken to doing this in the last few times I have given the team exam more as a way to help the struggling students, than as a way to advantage the stronger students. My logic, although I admit arguable, is that if a struggling student is placed with a strong student they will most likely obtain a high grade on the second exam, and therefore feel more confident that they can pass the course. This will most likely be a false feeling of confidence, unless they learn a great deal from the stronger student. If the struggling student does not recognize their lack of understanding of the course material, they will continue to do poorly in the course, and may fail. However, if the same struggling student is placed with another struggling student, they may realize the situation and work at learning the material instead of simply relying on their partner to pull them through. I have not done any formal assessment of this so I can not draw any formal conclusions on its effectiveness. I have found this affects only a limited number of students, no more than a handful in a class of approximately 70. As will be seen later however, it may have an impact on the distribution of grades on the team exams.

While I have been asked every time I give the team exam to let the students choose their own partners, or to let them take the exam with their homework teams, I have not tried either of these options. An additional reason for assigning the exam teams is to give the students a different type of teaming experience; a short term, intensive, time-on-task experience. While most students do not think they will experience this in their engineering careers, I have been assured by practicing engineers that they will. It is common for teams to convene for a single day to solve a problem. The people on these teams may, or may not, have worked together previously, and they must, in a short period of time, determine how to work best as a team to solve the problem at hand. The team exam gives students some exposure to this type of activity. In order to simulate this as closely as possible, it would be necessary to assign the team the day of the exam, or in the extreme, as the students enter the exam room. This however would be far too stressful on the students, and therefore the exam teams are announced one and one half or two weeks prior to the exam. It is the responsibility of the student to meet his/her partner, and determine if they are going to get together before the exam. In spite of the advanced notice, it is not uncommon for students to meet their exam partner for the first time just before the start of the exam. No attempt has been made to determine if exam performance correlates to the team members studying together before the exam.

Since this is a new testing format for most students, there is a fair amount of anxiety that may be expressed before the exam. It will be necessary to ally some fears before the day of the exam. Encourage the students to meet with their exam partners before the exam and even study together if possible. There is a real fear among the students of "letting a large portion of their grade depend on someone else." Expect these comments, and try to point out the positive aspects of the experience to ally their anxieties.

III. Administering the Exam

The environment in which a team exam is given can be critical to its success, therefore there are a number of items which should be considered. Since it often takes longer for two people to agree on the best solution method for a problem, more time must be given for the team exam. I typically schedule two hours for a three question team exam. I inform the students that the exam is not constructed to last two hours, but they are given that amount of time to facilitate the teaming process which naturally takes longer. Given this two hour length, it is necessary to schedule the exam in the evening. In addition, in order to facilitate interaction among the team members, I reserve a room which has long tables and not just side tables on individual chairs. A lecture hall with row tables works just fine for groups of two, but is a bit awkward for groups of three.

One very important difference between the manner in which a team exam is given versus an individual exam is the means by which the problems are given to the students. In an individual exam all of the problems are given to the student at the beginning of the exam. If this is repeated in a team exam, it is possible for the students to split the problems between them at the beginning of the exam and never interact to solve any of the problems. Since this is not the intent of the team exam, an alternate strategy has to be implemented. At the beginning of the exam I use an overhead projector to show the entire class the three problems on the exam, including the points allotted to each. They are then given a chance to talk and decided which of the three problems they would like to solve first. The appropriate problem is handed out to each team and the exam

begins. Once they have solved the first problem, or have become stuck, they can hand in that problem and receive one of the remaining problems. They must also hand in any work they have done on the first problem. This process ensures, to the greatest extent possible, that they are working as a team on each problem. They can reclaim any problem as often as they like, but they can work on only one problem at time. Since the paper shuffling can become excessive for more than 25 teams, I have found it helpful to bring a graduate student along to help. By the end of the exam, each team must hand in only one solution to each of the problems for grading.

As may be suspected, the atmosphere in the team exam room differs a great deal from that in a traditional exam. Since students are working together there is always a constant noise level in the classroom. While one may think this would be bothersome during an exam, I have received only one complaint about the noise level being a disturbance. The students are very focused on their own exams, and therefore do not seem to notice the talk of others occurring around them. In addition to being a noisier environment, it is also a more relaxed one. The usual tension which invades an exam room is remarkably absent during a team exam. Students, while working hard, are noticeably more relaxed, even going as far as to put their feet up on the chair in front of them. This relaxed atmosphere can be even more pronounced, as during one of the exams I had a team of two women who laughed during a large portion of the exam. When one of them came up to the front of the room to change problems, I commented on their laughter. The response that I received was that they were “just having so much fun.” Now, what a surprise that was to hear! Indeed, I can say that this is an enjoyable exam to give, not only because the anxiety level is greatly reduced, but also because it is fascinating to watch the students working together in the problem solving process; something that we as instructors do not witness often enough.

IV. Post-Exam Activities

The grading of the team exam is conducted in the same manner as an individual exam. There is no differentiation between team members, so both members receive the same grade on the exam regardless of their relative contributions. The students realize this before the exam is given as it is clearly stated in class. When the exams are handed back to the students it is made clear to them that the grade they received may not reflect their knowledge of the material, and that only they can accurately assess their contribution to the exam. It it also stressed that the material covered on the exam will be needed on the last hour exam and on the final exam. Therefore, if they feel they have not yet learned the material they need to do so immediately, and are encouraged to seek help if it is desired.

Upon the initial implementation of the team exam, the grades improved dramatically, as can be seen from Figure 2. However, over the years there has been some variation in the results, as can also be clearly seen from the figure. This may be attributed to the varying degree of difficulty that can occur from exam to exam, or to a variation in student ability. Different results are observed if the final exam is included in the average as shown in Figure 3. When the final is included, a consistent trend is observed. That being the team exam has a higher grade than the average of the other three exams.

Another interesting observation can be made by looking at the standard deviation in the grades on Exam 2, both before and after the team exam. Before the team exam the average standard

deviation in the grades is 11.4 while after the implementation of the team exam the average standard deviation is 11.3, showing that the variation in the scores is identical. This result is somewhat surprising, as in previous reports the standard deviation for the team exam was smaller[4,5]. This may be due to the adjustment that breaks up the initial student pairings which demonstrate large differences in abilities. A closer look at all the exam grades will have to be conducted to determine if this is the cause for the difference.

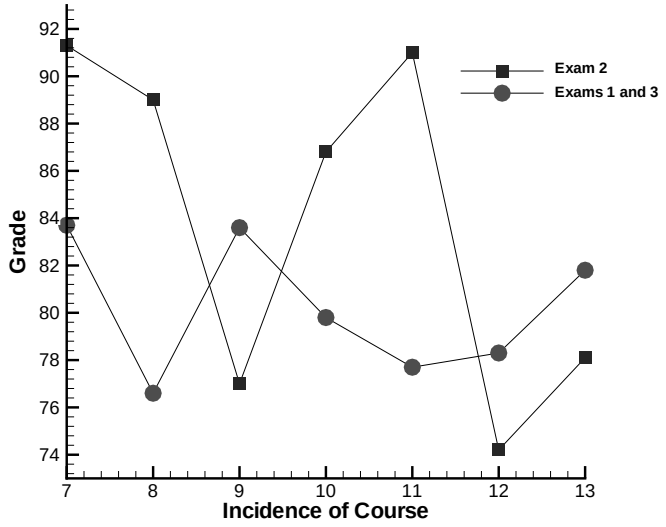


Figure 2: Grades for exams given after implementing teams for Exam 2.

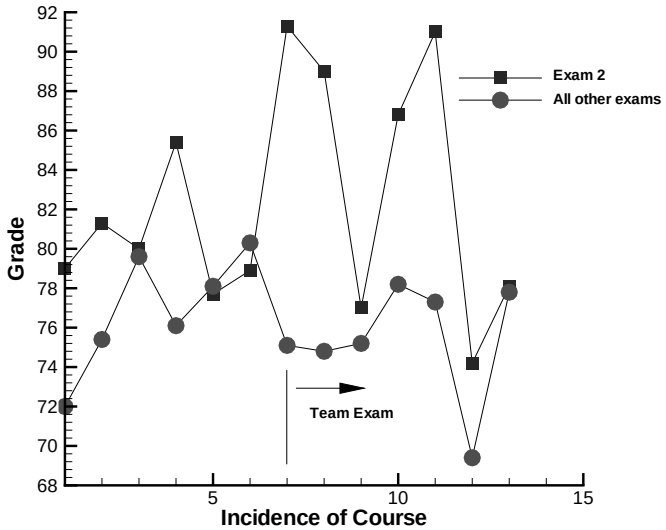


Figure 3: Grades for Exam 2 and average of all other exams including the final.

In all cases, anonymous student feedback was solicited after the entire team exam experience was complete. While some of the comments were to be expected, others were somewhat surprising. The overall opinion of the students is that they like the team exam concept, some so much so that

they have convinced some of my colleagues at Michigan Tech to implement a team exam in other courses. Others appreciate being able to have someone to check their work, or to talk to about the problem and how to solve it. In most circumstances they come to the realization that two heads are better than one. In one or two instances there have been major problems between the team members during the exam which have caused the team to be dysfunctional, and therefore unable to satisfactorily complete the exam. These cases were handled on an individual basis, and I want to stress this has only occurred only once or twice from among nearly 200 teams. The more common statement expressing dissatisfaction with the exam is that the stronger student feels they carried the team, and therefore their exam partner did not deserve the grade that they were given. Fortunately, I have also seen the other side of that comment from the weaker student, although admittedly less frequently. The weaker student, having worked along side the stronger student, realizes they can look nowhere but to themselves for their lack of performance. They can not blame the exam, or the instructor! This may in fact be one of the unforeseen benefits of the team exam, as the weaker student realizes that they do not know the material and therefore must study harder in order to successfully complete the course.

V. Summary

The implementation of a team exam into a first thermodynamics course can indeed be accomplished, and can have a number of benefits for the students. Students can not only gain valuable experience by participating in a short term, intensive, time-on-task team assignment, they can also more effectively demonstrate their knowledge of the exam material, or realize their lack thereof. This is evidenced by the higher average grades on the team exam with very similar grade distributions compared to individual exams, and from student comments. If constructed correctly, the team exam can also serve as a learning experience for all students by providing greater challenges than an individual exam. While problems with team dynamics can arise during these experiences, they have been found to occur with only a small minority of the students, and therefore do not out way the benefits that are gained.

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