Challenges and Evolution of Combined and Separate Thermodynamics Courses in a Mechanical Engineering and Mechanical Engineering Technology Program

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Abstract

In 2010 the engineering department at Eastern Washington University added a mechanical engineering (ME) program to its already established mechanical engineering technology (MET) program. As part of the transition new courses were developed for the pure ME program and some were redesigned to include both programs. Thermodynamics, for instance, was taught as a single class for both ME and MET students initially, with the same outcomes and requirements for each group. This coupled-course approach was also taken for other courses, as deemed practical and appropriate. This resulted in challenges to both the students from each group as well as to the faculty. MET students, for instance, were required to take only calculus I and II while ME students often had already completed calculus IV and differential equations, resulting in a dilemma for faculty attempting to present a calculus-based curriculum. The students from each program also had different goals and expectations, which further made it difficult to design course content that was appropriate to all and also meet the program requirements. To address these issues, in 2013 the thermodynamics course was split into two separate courses for ME and MET students, with very similar student pre- and co-requisites, similar program objectives, and curriculums established specifically for each program.

Throughout the development of the new ME program, student learning data was collected for all students going through both the ME and MET thermodynamics course (as well as other courses), in order to help inform the faculty on how well the courses were meeting objectives. Two specific assessments were used: a student survey addressing how well the course met the course objectives and assignment grades tied to each course objective. Results from these assessments have helped direct the continuous development of these courses over the past several years. The objective of this paper is to present these data and the evolution of the thermodynamics course from purely MET, through combined ME & MET, and finally to the separate ME & MET courses. A qualitative review is also given on particular student challenges and impacts and on the program's experiences throughout this transition and development.

Background

Thermodynamics is a core course of any ME or MET program. To most students, this is a particularly challenging course as the concepts involved are more abstract than other topics such as statics or strength of materials. Most of the students can readily understand the concepts of heat, energy, and work, but the interaction between all of them is often what is challenging. The use of charts and tables can be overwhelming for some. Power cycles can also be tricky to comprehend as some of them are purely theoretical (such as the Carnot cycle) and do not have a direct application in real life. The science and laws behind thermodynamics and the implications involved are what govern many of the real life applications such as the refrigeration cycle, diesel and internal combustion engines, etc.

The students taking the class should have a strong mathematical background, although the math involved in solving the problems is not particularly that challenging. More math is required to derive the governing equations than for solving problems. As a result, this particular course has proven to be fairly challenging for the Mechanical Engineering Technology students who may not be too comfortable with some of the more advanced mathematical concepts. Eastern Washington University (EWU), a regional university in Washington State, has been offering the BS in MET program for many years and the BS in ME since 2010. The major difference between the two programs resides in the amount of pre-requisite math needed. MET students are required to complete up to Calculus II while ME students are required to take Calculus IV and Differential Equations. This difference in the math levels makes it very challenging for some math intensive courses such as Statics and Dynamics to be combined into one single course for both ME and MET. Even though the two programs are similar, the goals and expectations of the students are different. The Engineering & Design department at EWU first adopted a combined approach, i.e. a single course for both programs. During the 2012-13 academic year we decided to split the statics/strength of materials/dynamics sequence into two separate courses, one for the ME and one for the MET and Construction Management programs. Based upon the data presented below, we decided to split the courses for thermodynamics and fluid dynamics during the 2013-14 academic year. While the main topics are identical, the ME version goes into more depth and more math than its MET counterpart.

Literature Review

While researching other models of ME/MET dual classes – thermodynamics in particular and engineering/engineering technology in general – there seems to be little published on the topic. However, many authors have presented similar types of challenges that both ME and MET students have in advanced engineering courses, which are rooted more heavily in calculus and differential equations, as discussed above. As an example, Bluestein[1], in addressing core deficiencies of ME majors entering thermodynamics, developed a prerequisite assessment for students that focused heavily on math topics, with the intent to guide earlier preparation for the course. Kadlowec, Chen, and Whittenghill[2] presented a study on student learning in mechanics, finding that "*student scores in a Statics course were significantly associated with their prior performance in Calculus II and Physics I.*" These results are not surprising as Calculus II can oftentimes be the tipping point for struggling ME students who, at this point, decide to shift to the MET program with no further math courses. While Statics is a lower level course than Thermodynamics, the correlation is similar between the math and engineering concepts and inline with our observations at EWU.

In a study by Dempster, Lee, and Boyle[3] on teaching of Thermodynamics and Fluid Mechanics, the authors identified some of the main issues they found students had difficulty with. From their paper:

> *The development and use of the numerous concepts and equations to solve Thermodynamics based problems require continual overviews and summaries to show the connection between the big picture and the details. The link between the basic physical principles, the mathematical representation and numerous constitutive relationships (ie property relationships, process paths, etc) are particular troublesome.*

As the authors suggest, understanding and learning thermodynamics uses links to the mathematical formulae, which is a significant struggle for some students. This suggests that students weaker in math have less of this type of foundational experience to build the new thermodynamics concepts on, making the concepts even more abstract to them.

While looking for other cases of dual ME/MET classes, there is little literature that could be found. This is surprising since the dual enrollment is not novel and is common for courses that include seniors and graduate students, for instance. For this situation, there is often a slight difference in the objectives for the graduate students, usually resulting in advanced work and/or projects. Some instances of dual enrollment were found for lower-level courses. Pennsylvania State University, for example, combines engineering and engineering technology majors in their Introduction to Engineering Design freshman course[4]. Their goals are primarily to present early on to students the options available for each program as well as retention/recruitment. Other schools were also found that combine the lower-level courses. Oregon Institute of Technology combines many of their lower-level courses that are common to ME and MET majors[5]. However, their thermodynamics is offered in two courses – a Thermo I and II sequence – and only the Thermo I is common. Their Thermo II course is split into two course, one for ME and one for MET.

Many schools with both ME and MET programs often do not integrate their courses. As highlighted by Brower[5], most of these dual programs do not even reside within the same department, and some are even in different colleges within the same institution. Our experience to-date at EWU with our new ME program, which is within the same department as the MET program, has shown that having both majors in the same thermodynamics class is challenging, for both the student and instructor. The difficulty MET students have with the advanced math and theory in thermodynamics is well documented in the literature, and appears to be a common cause for spitting the course into two.

Data analysis

As part of our continuous improvement process we have both the instructor and the students evaluate how well the course objectives were met during the term. The course objectives are listed in Table I and are also tied to the ABET 3a-k for both EAC and ETAC which are not listed. The prerequisites for this course are Calculus I & II (differential and integral calculus), Physics I & II (energy, motion, fluids, and thermodynamics), and Technical Writing. Currently we do not do before and after assessments of student knowledge related to the course, but we are planning to develop such assessments of both prerequisites and key concepts in the future.

Table I Course Objectives for Thermodynamics

1. Use scientific language to describe heat, temperature, pressure, work, and energy.
2. State and apply the 1st Law of Thermodynamics for flow and non-flow systems.
3. Identify processes and properties related to energy storage, transport, and transformation.
4. State and apply the 2nd Law of Thermodynamics and describe reversible and irreversible processes and define thermal efficiency.

5. Explain the Carnot cycle and its importance in Thermodynamics.
6. Sketch the p-v and t-v diagrams for steam.
7. Determine material properties using tables and charts.
8. Solve problems using the ideal gas law.
9. Identify and analyze various power and refrigeration cycles.
10. Compare thermodynamic cycles and heat transfer process in the lab with theoretical performance.
11. Compute rates of heat transfer in solids and liquids using theoretical and empirical methods.
12. Understand the historical nature of codes and regulations for power systems and the role of professional societies in their development.

The following figures present the evaluation of the course objectives as thermodynamics was taught during the Fall terms of 2010 through 2013. During the Fall 2010 term it was taught to 1 ME and 35 MET students. During the Fall of 2011 it was taught to 18 ME and 18 MET students. The Fall 2102 course was taught to a mix of 27 ME and 10 MET students. Finally during the Fall 2013 the course was split into separate sections for ME and MET students. The combined ME/MET course was taught by the first author during the 2010, 2011, and 2012 Fall terms. The Fall 2013 ME course was taught by the second author while the first author taught the MET class using the same text at the third author had used for the MET course in 2008 and 2009 from which data are not available in the same format as presented here.

Figure 1 presents the instructor evaluation of the student performance for each of the course objectives. The student evaluation was based upon their scores on a mixture of homework, quizzes, laboratory reports, and exams that covered the topic. The mixture of these 4 elements would change from topic to topic, but similar combinations of the instruments were normally used from year to year. The average percentage scores on each instrument in a topic were averaged and then converted into the 0 – 4 grading scale used at EWU. Key points on this scale are 1.0 = 60%, 2.0 = 70%, 3.0 = 80%, 4.0 = 95%. Examination of this chart shows that during the Fall of 2011 and 2012 the MET students generally had lower scores than the ME students when the courses were taught to the combined class. On the other hand, the MET and ME scores were both fairly constant from term to term for some of the topics indicating that the level of student performance was consistent. It should also be noted that the scores are particularly low in the middle of the chart for objectives that tend to be more abstract and are not covered as well in the laboratory portion of the course.

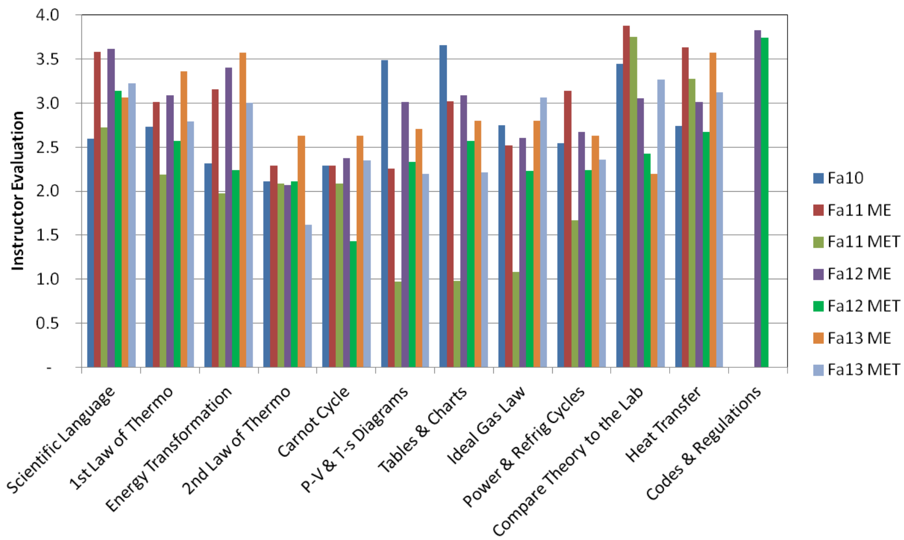

Figure 1 Instructor Evaluation of the Course Objectives

Figure 2 shows the student perception of the same course objectives where the results for ME and MET students were combined during the Fall 2011 and 2012 terms since this was before ABET advised us to separate the scores. The student perception of how well the course objectives were covered is much more consistent than for the instructor evaluation of their performance and only falls of appreciably for Codes & Regulations – an area we have not found a good way to assess. The Fall 2013 MET scores for student perception were similar and in many cases lower than when the combined course was taught during 2012. We attribute this to: 1) the instructor making an incomplete transition from teaching the calculus based version, 2) an incomplete transition to a flipped classroom, and 3) a change in the nature of the questions asked by the students from probing the concepts to how do we do this which was related to the first issue.

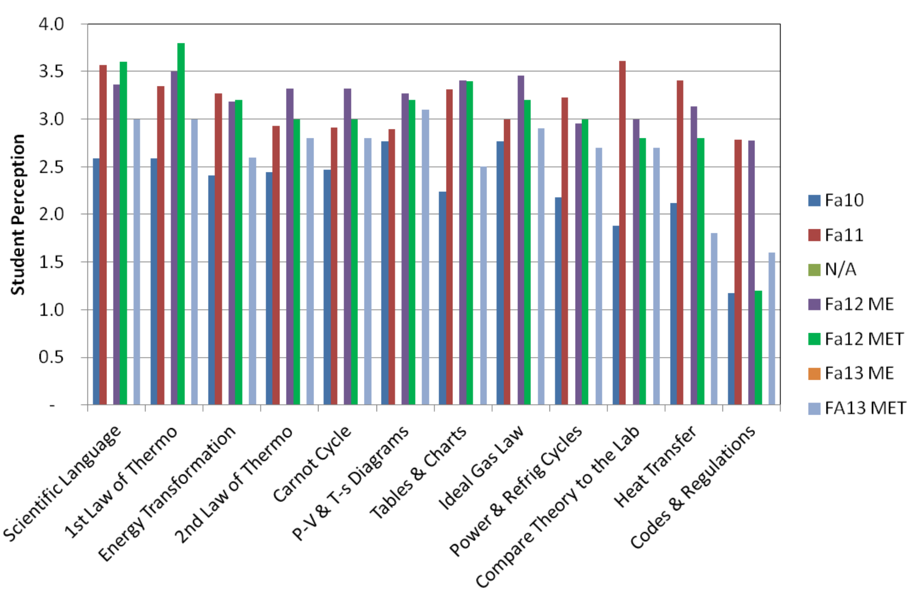

Figure 2 Student Perception of the Course Objectives

Figure 3 shows the difference in both the instructor evaluation (IE) and student perception (SP) for the ME vs. the MET students. In most cases the scores for the ME students were much higher than those of the MET students. The major difference is for the student perceptions during the Fall 2012 term where the scores were very similar and in some cases the MET students scored an objective higher than the ME students. It will be very interesting to see if this trend hold when the Fall 2013 scores are all available in so they can be added to the final version of the paper.

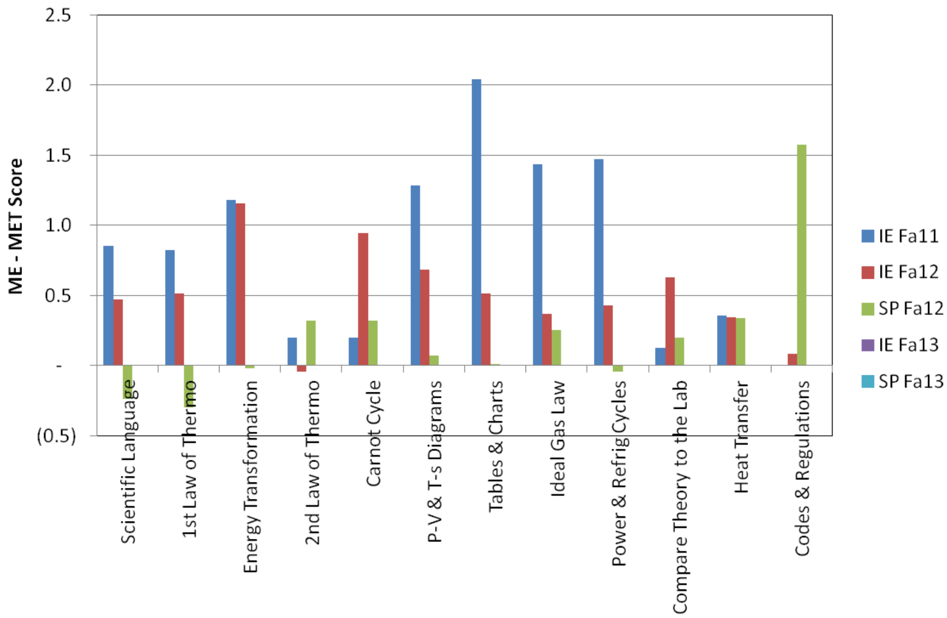

Figure 3 Difference between ME and MET students for evaluation of the Course Objectives

Discussion

The ME and MET sections of thermodynamics used the same set of course objectives as listed above, but used different textbooks. The ME section used Moran et. al.[6] which was used for the combined courses in 2011 & 2012 while the MET section used Rolle[7] which was used in 2010 and in previous years when the course was taught to only MET students (and 1 ME student who switched majors). The change to Moran et. al. was done since it took a calculus based approach which better matched the ME curriculum. We did not believe that this would present any problems to the MET students since they will have completed both differential and integral calculus prior to taking thermodynamics. In addition, the hardest calculus was the integrations needed for ideal gas and polytropic work that are reviewed in class.

One of the observations from the combined classes is that the MET students tend to struggle more with the homework than the ME students. During the two years of the combined course the MET students consistently scored 10 – 20% lower on the homework assignments as a group than the ME students. On the other hand, the scores of the two groups on the quizzes, labs, and exams were generally closer and the MET students sometimes had the higher average. We believe that this is due to several factors.

- The homework problems tend to be more difficult than the problems on quizzes and exams since the students had more time for the homework. The ME students could focus on the more difficult concepts rather than tasks such as finding the correct values from the tables or via interpolation.
- Solutions to the homework were provided as a study aid prior to the exams which leveled the playing field between the ME and MET students.
- Experiments and most lab reports were done in mixed groups of ME and MET students.

To address the homework issue, the instructor decided to flip the classroom for the Fall 2013 MET section so that he could spend more time on in-class problem solving. Due to not understanding how large an effort this is and a range of technical issues only the first four weeks of the ten-week class were flipped, the remainder was taught in a more traditional lecture format. However, significantly more time was spent in class on problem solving than in previous terms, which resulted in somewhat higher homework scores. The incomplete flip of the classroom was felt to be responsible for some of the low student perception scores since heat transfer and codes and regulations were being covered during the transition from the flipped to traditional format. Although flipping the classroom was not a success this year, we believe that it can work for this class if well implemented since it will allow more time for problem solving.

Once all of the student perception data for fall 2013 has been collected it will be included in the final version of the paper.

Conclusions

Even though a basic class in engineering thermodynamics does not require math beyond the first two courses in calculus, we have found that the amount of math taken by ME and MET students has an effect on how well they do in the course. We attribute this to the ability to quickly do the required mathematical manipulations that often only require algebra so they can focus on the more abstract concepts in thermodynamics. The MET students get hung up on the math so they have less time to focus on the thermodynamics. Creating separate courses for ME and MET students has allowed us to make sure the MET students are familiar with the basic math before they confront the more difficult issues. This has increased how well the MET students understood the course concepts based upon the instructor's evaluation, but has had a small or slight negative impact on their own perceptions of how well they did – a point that will have to be addressed the next time the course is taught.

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