120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #6107

A Gentle Bridge between Dynamics and Thermodynamics

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Abstract

Engineering Thermodynamics is a stumbling block for many engineering students, as it introduces many new concepts and uses completely different approaches in solving problems. Therefore, a bridge between the knowledge of the previous courses and this course is very useful. *Engineering Mechanics-Dynamics* is a required course that is familiar to most students, and thus the idea of the conservation laws there can be carried over. With this approach, we found that the barrier in concept and methodology is lowered significantly. In the assessment at the end of the semester, the statistical result shows that the challenge levels of these two courses perceived by the students are identical.

I. Introduction

Thermodynamics has a long history of development and now it is applied to many disciplines beyond science and engineering.[1-3] In the 17th century people investigated the relationships between temperature, pressure and volumes of various gasses; in addition, the prototype of the steam engine was invented. In the 18th century the steam engine became practical, and thermodynamics is the theory behind this new machine that powered the industrial revolution. In the 19th century the laws of thermodynamics were formulated, and the concept of entropy was introduced. In the 20th century the theory of thermodynamics was expanded into many different fields, such as information theory, economics and sociology, etc.

Unlike courses such as *Engineering Mechanics*, *Engineering Thermodynamics* deals with energy and entropy of fluid, which is much more complicated than point particles and rigid bodies. However, unlike *Fluid Mechanics*, *Engineering Thermodynamics* does not look into the detailed field distribution of temperature, pressure, and velocity, and thus it does not need to engage advanced mathematics, such as vector calculus and partial differential equations. Therefore, students should be able to learn this course without too much difficulty.

Every young instructor, who teaches *Engineering Thermodynamics* for the first time, feels that it is very challenging to transfer his/her own understanding to the students. After teaching this course several times, many instructors figured out their own way to improve teaching effectiveness and shared their experience in publications. One approach is to use advanced technology to enhance the effectiveness of learning, such as multimedia and CAD simulations.[4-8] Another approach is derived from cognitive science, and the knowledge in this course is divided into three categories: declarative, procedural, and conditional knowledge.[9] We adopted an integrated approach, which can be effectively applied to learning the knowledge in all these three categories.

II. Conceptual Bridge

Most students consider *Engineering Thermodynamics* a very challenging course, which quenched the passion of many promising students pursuing a career in engineering. One culprit is the new approach relying heavily on data tables and diagrams to analyze and solve problems, since the familiar mathematical tools of calculus and vector analysis are not very effective in dealing with the properties of fluids in such situations. Therefore, most students are at a loss at the beginning of this course, and some of them do not get the idea until the end of the semester. It is very difficult to learn a completely new approach, but it would be much easier if an analogy can be found using something that students are already familiar with. Fortunately, energy conservation is the first law of thermodynamics, and a special form of it is used in *Engineering Mechanics-Dynamics*, thus students can see the similarity in these two different situations. By adopting this approach, students can get the idea at the beginning, and as a result, *Thermodynamics* is transformed into an easier course.

State and properties are central concepts in *Engineering Thermodynamics*, which are the content of the data tables at the end of the textbook.[10] What students need is an integrated idea of these parameters so that they can see the relationships in various processes. Actually, we can also define state and properties in *Engineering Mechanics-Dynamics*; for example, the state of a flying bullet can be described by its position, velocity, momentum, energy, etc. When this bullet penetrates through an apple, these parameters will change, and this is similar to a process in thermodynamics.

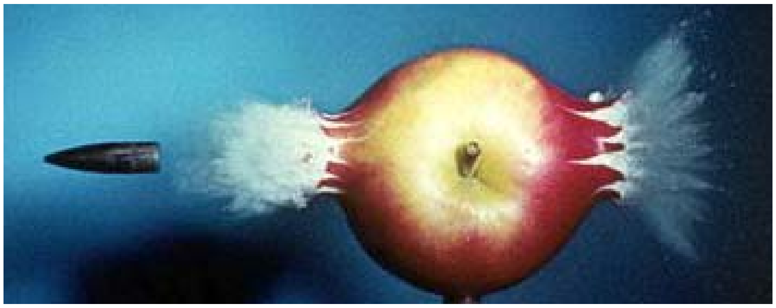

Fig. 1. An apple is penetrated by a bullet.

At the beginning of the course, Fig.1 is shown to the students, and the following question was raised: How to calculate the energy absorbed by the apple. Most students realized that it is impossible to measure the minute change in structure and temperature of the remaining part of the apple, let alone tracking the small pieces flying in every direction. Therefore, the only way to find the answer is to compare the initial state and the final state of the bullet. Then students are asked to identify the state parameters of the bullet, such as mass, velocity, momentum, kinetic energy, temperature, etc. By means of this simple example with a vivid picture, students can construct a prototype of the important concepts in thermodynamics, such as *state, property* and *process*.

From another point of view, the concepts of state and properties are also very helpful in learning *Engineering Mechanics-Dynamics*. In this course, the concepts of linear momentum and angular momentum, kinetic energy and potential energy are introduced in different chapters. Students are very comfortable in solving problems while learning these individual conservation laws, but they have big trouble during the final exam when they need to decide which law applies to a specific situation. By sharing the concepts in these two courses, students can learn both of them more effectively.

III. Assessment Result

Students are assessed in two different ways. First, standard problems in the FE examination are included in the final exam, which can be used as an objective evaluation of learning effectiveness. Second, students were surveyed on the challenge level of this course, with the course of *Engineering Mechanics-Dynamics* as a reference.

1. Testing Result

Five diagnostic examination problems from ref. 11 (DE VIII #1, 2, 4, 6, 8) are included in the final exam. There are 17 students enrolled in this course, and the test result is shown in Fig. 2, where the height of the bars stands for the number of students who got the answer right. The first problem is about the conversion from volume ratio to quality of a mixture of steam, which was covered at the beginning of the semester. It seems to be a very easy problem, unfortunately, only two students chose the correct answer, while most students didn't pay much attention of the difference between volume ratio and mass ratio. The second problem is on specific heat of liquid water, 13 students got the right answer. The third problem is on the first law of thermodynamics, but a few students were distracted by the additional information on volume and pressure, and only 12 students got the right answer. The fourth problem is on a control volume condenser in a steam power plant, which seems to be a pretty messy problem, but only one student got it wrong. The last problem is the calculation of the entropy change of ideal gas, only two students didn't get the right answer. As we know, usually there are a few students in a class who did not fully engage in learning throughout the semester. Therefore, this result indicates that the students learned this course pretty well in general, but the first problem is an exception.

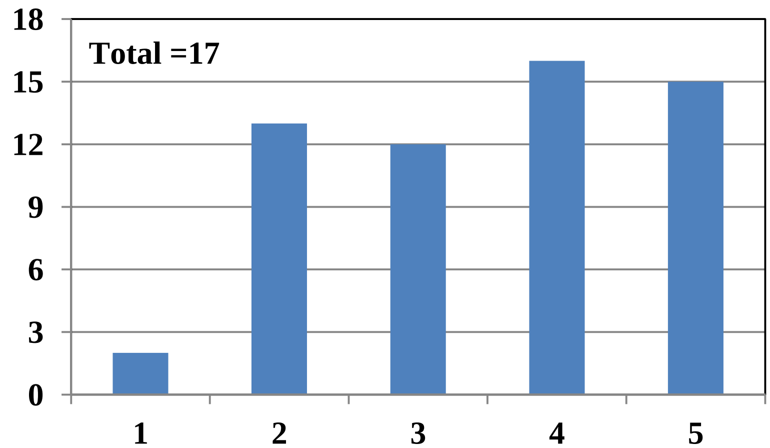

Fig. 2. Assessment result of FE diagnostic examination problems.

2. Subjective Perception

During the last lecture in this semester, students were surveyed on the challenge level of this course, with the course of *Engineering Mechanics-Dynamics* as a comparison. The challenge level is divided within the range from 1 to 5, where '1' stands for the easiest and '5' refers to the most difficult. Two students didn't show up in this lecture, and the survey result of 15 students is shown in Fig. 3, the height of the columns stands for the number of students who selected the corresponding number. Seven students consider this course at an average level, and five students consider it more challenging than average, and two students consider it very challenging. It is interesting to note that these two courses have identical average of 3.93/5, and it indicates that students consider this course no more challenging than the course *Engineering Mechanics-Dynamics*.

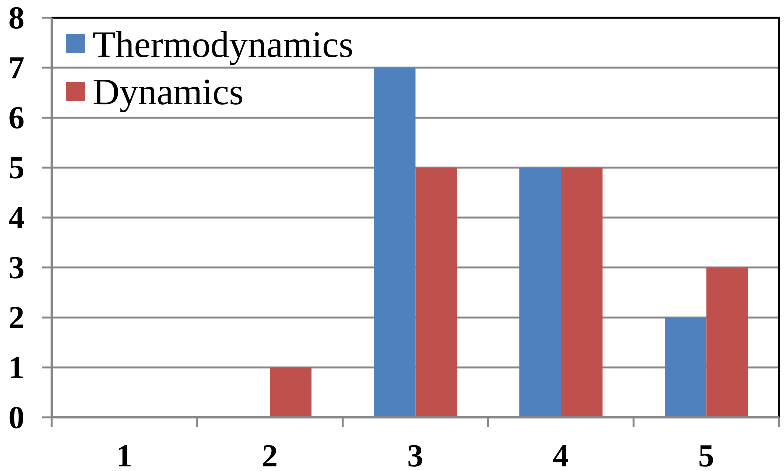

Fig. 3. Comparison between *Thermodynamics* and *Engineering Mechanics-Dynamics*.

IV. Conclusion

The methodological transition in learning *Engineering Thermodynamics* is a major barrier for students, which can be effectively lowered by using an analogy with the knowledge learned in the course of *Engineering Mechanics-Dynamics.* The assessment result shows that most students learned this course pretty well, at the same time, they consider these two courses at the same challenge level. As most students didn't have much trouble in learning *Dynamics*, we can draw the conclusion that this approach is a very effective bridge bypassing the barrier in learning *Thermodynamics*.

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