Paper ID #16312

Student Learning Materials for Ability Enhancement in an Engineering Course

Dr. Kristine K. Craven, Tennessee Technological University

Dr. Kris Craven is currently the Interim Director of the Basic Engineering (BE) Department and a tenured Assistant Professor of the same department at Tennessee Tech University (TTU). I have been employed by TTU since 2000 primarily teaching in the Basic Engineering Program. I have also been teaching junior level courses for the Mechanical Engineering department for several years. In addition to ASEE, I am a member of the Society of Women Engineers, American Society of Mechanical Engineers, Sigma Xi, and Pi Tau Sigma.

One of my passions is freshman engineering students. I truly enjoy teaching and working with the first-year students. Another passion is outreach activities. I have participated in the starting and running of three different outreach programs that are working to increase the number of female engineering students by getting young girls interested while still attending primary school.

Teaching Students to Retrieve Property and State Data in Thermodynamics

The material presented here is being implemented in a junior-level Thermodynamics I course taught in the Mechanical Engineering department. Students in other engineering departments may take this course as a technical elective credit; however, those students represent a minority of the overall population. Therefore, the author approaches this course in a manner so that enrolled students will be prepared to excel in Thermodynamics II, which is a required course in the Mechanical Engineering curriculum. As such, certain skills and knowledge must be attained by the students that will be further expanded in the sequence course. It is easy to over-emphasize the laws of thermodynamics and the various solution techniques while devaluing the retrieval of the state and property data for the substances being analyzed in the problems. Unfortunately, if students use the proper solution technique with the correct equation(s), they will still get an incorrect answer if the property values are wrong. It is believed that spending a sufficient amount of time to teach this skill is very beneficial to the students and necessary for success in both thermodynamics courses.

Thermodynamics I looks at the primary laws of thermodynamics and some additional conservation equations along with the application of these when analyzing various processes and cycles. Although the zeroth law is critical in measuring temperature, it is only given a trivial amount of coverage due to its simplicity and the fact that it is not actually used in the analysis of thermodynamic systems. The first law of thermodynamics examines the conservation of energy during a process and often involves the volume, temperature, pressure, internal energy, and/or enthalpy of the substance. It can be used to determine the amount of work or heat transfer, or to evaluate an unknown state of the substance. If the process being analyzed involves mass flow across the boundary, then a conservation of mass must also be considered. The second law of thermodynamics analyzes the conservation of entropy and often involves many of the properties listed previously with the addition of entropy. This law can be applied to a process to determine its direction, to understand the heat transfer requirements, or to evaluate an unknown state of the substance.

The types of substances involved in the processes analyzed in this course fall into one of several categories. Some substances will follow special analysis techniques such as solids, incompressible liquids, and ideal gases. These types of substances are not under consideration here. Rather, the topic of discussion is the type of substance that requires the use of tables in order to determine the state and property data that are required for the problem solution. These substances include steam/water, refrigerants, ammonia, propane, etc. Because each of these substances reacts differently to changes in temperature and pressure, tables are needed to identify the correct values for volume, internal energy, enthalpy, and/or entropy for the process analysis. In order to get a complete picture of how the properties vary with temperature and pressure, as well as being able to fix the state, students must be able to work with Saturation Tables, Superheated Tables, and/or Compressed Liquid Tables.

Each exam in this course includes several problems that involve using the property tables and the retrieved properties in their solution. It was observed that many of the incorrect answers on the exams were due to the use of incorrect property data in the problem solutions, as opposed to an incorrect solution technique. Unfortunately, it is difficult to independently track quantitatively the effect of the two separate factors. However, since the observation was made, the author has been continually developing classroom strategies for improving the student's ability to accomplish this crucial task. The gradual implementation of these techniques has further complicated the ability to obtain quantitative results on the effectiveness of the techniques being presented here.

The first intervention was to incorporate online quizzes through the eLearn software. It was noted that there is a sufficient amount of material presented in the chapter of the textbook, but a relatively small number of homework problems when compared to the other material being presented in the chapter. It was also realized that retrieving correct property data requires a thorough understanding of several concepts. The online quizzes were developed in a way to combat both of these issues. Unfortunately, a significant improvement was not seen and it was noted that the students were not taking the quiz as intended. After attending an ASEE conference and combining a number of interesting ideas, the BINGO game was developed. Again a significant improvement was not seen and it was noted that the students did not adequately prepare for the game, so the game was not effective at that time. Therefore, a different method was needed to force the students to spend more time in perfecting this skill in order to be prepared to make the best use of the game. An additional assignment was designed and the decision was made to devote a class period to the new assignment. A more detailed discussion of the current implementation of the combined techniques follows.

The lessons begin with a classroom discussion of the 3-d p-v-T surface using a demonstration model for water that has been color coded to highlight the areas representing the various phases (or states) of the substance. This model also shows the other important lines that will appear on the surface. Reference is made to 2-d illustrations in the textbook that attempt to show this 3-d surface. There are two basic types of surfaces, those that expand when frozen and those that contract when frozen. The similarities and differences are referenced in the textbook and only briefly discussed in the classroom. Students are encouraged to read the textbook for more information as needed.

The lessons also include an introduction to the two dimensional p-v and T-v diagrams that are used throughout the course, and how they are projected from the three dimensional surface. Using the white board, the 2-d diagrams are drawn, and terms such as isobar, isotherm, and vapor dome are introduced. Time is spent on phase change and the how the areas from the 3-d surface correspond to the 2-d diagrams. It is important to point out that one key component of correctly identifying values for the properties of the substance is to first be able to identify the phase, or fix the state, of the substance. For these types of substances there are 5 distinct phases that are identified: compressed (or subcooled) liquid, saturated liquid, saturated mixture, saturated vapor, and superheated vapor. The saturated mixture phase is where both saturated

ME 3210 - Thermodynamics I / Determining State and Property Values

Given Temperature (T) & Pressure (p):

$T < T_{sat}$ for given p	Subcooled/Compressed Liquid	USE properties from Compressed Liquid tables OR
		USE v_f, u_f, $h = h_f + v_f (p - p_{sat})$, s_f @ **T** from saturation tables
$T = T_{sat}$ for given p	Saturated Mixture	NEED more information
$T > T_{sat}$ for given p	Superheated Vapor	USE properties from superheated tables

Given Temperature (T) & Any property r (v, u, h, or s):

$r < r_f$ for given T	Subcooled/Compressed Liquid	USE properties from Compressed Liquid tables OR
		USE v_f, u_f, $h = h_f + v_f (p - p_{sat})$, s_f @ **T** from saturation tables
$r_f < r < r_g$ for given T	Saturated Mixture	DETERMINE the quality (x), USE it to find properties, $p = p_{sat}$
$r > r_g$ for given T	Superheated Vapor	USE properties from superheated tables

Given Pressure (p) & Any property r (v, u, h, or s):

$r < r_f$ for given p	Subcooled/Compressed Liquid	USE properties from Compressed Liquid tables OR
		USE v_f, u_f, $h = h_f + v_f (p - p_{sat})$, s_f @ p from saturation tables
$r_f < r < r_g$ for given p	Saturated Mixture	DETERMINE the quality (x), USE it to find properties, $T = T_{sat}$
$r > r_g$ for given p	Superheated Vapor	USE properties from superheated tables

Figure 1: Class Handout for Fixing the State and Finding Property Data.

Properties Table Assignment

Using Water, fill in the missing information in the table below. Also show the first 6 rows on p-~~v~~ and T-~~v~~ diagrams, include the vapor dome, isobars and/or isotherms, and all appropriate labeling.

	T, ºC	**p, bar**	**x (%)***	**~~v~~, m^3/kg**	**h, kJ/kg**	**Phase****
1	50			7.72		
2		4				Saturated Vapor
3	240	5				
4	110	3				
5	140				1800.0	
6		9	0			
7	80			3.407		
8		140			3200.0	
9	130		65			
10	400				3096.5	
11		2	70			
12	90	75				
13	170					Saturated Liquid

*Use N/A when not saturated

**Choose from: Compressed Liquid; Saturated Liquid; Saturated Mixture; Saturated Vapor; OR Superheated Vapor

<u>Figure 2</u>: Additional Assignment for Finding Property Data Practice.

liquid and saturated vapor are present while the phase change from saturated liquid to saturated vapor is taking place. The quality is used to determine the correct values for the substance's properties while in this phase. This concept is presented, and its use for determining the properties of a saturated mixture is shown.

With a better understanding of the phases (or states) for the substances, it is time to introduce the Property Tables that will provide the property values for the substances being analyzed. These are: the Saturation Table(s), the Superheated Table, and/or the Compressed Liquid Table. These Property Tables are provided in the Appendices of the textbook for several substances. Figure 1 shows a handout that is distributed to illustrate how to find the correct value for any property given any combination of the pressure, temperature, and/or one other property. As can be seen, this handout provides a logical summary for fixing the state and retrieving the property data from the Property Tables. The purpose of the handout is for the students to develop their own method of determining the property value that is needed for the thermodynamic solution. Students are told that they are not required to memorize, or even use, the handout. However, they are often disappointed when they are informed that this table will not be allowed during the exams. Exams are open book and much of the information is available there, but the students should be able to perform this task without the use of additional materials.

When reading data from a table such as the Property Tables being discussed here, there are often values needed that are not directly listed in the table. When the value of the independent variable is not directly listed, then some technique is needed to retrieve the data. For this course, linear interpolation is used. Although students should have seen this technique in previous course(s), many have not been required to use it very often. Therefore two different methods for performing linear interpolation are also reviewed/taught at this time.

Once the handout in Figure 1 has been sufficiently presented, example problems from the textbook are worked. Unfortunately, the textbook only contains a limited number of homework problems that address the task of retrieving the data correctly as opposed to solving problems that require property data for their solution. It is felt that simply retrieving the correct property data is such a critical element of the course that more practice is needed. One class meeting is then devoted to the completion of the assignment seen in Figure 2. For this assignment, students are encouraged to work in small groups of 3 - 4 students. This allows for superior learning in a number of ways. Devoting a class meeting to this assignment emphasizes the importance of the work. By allowing students to work together, there is more accountability to contribute to the group. Finally, one of the best ways to learn something is to teach it. Allowing students to teach fellow students gives them the opportunity to explore the topic more thoroughly, possibly requiring them to give the explanation many times, in different ways. This will help both the students who are struggling and will help the student doing the explaining to solidify his/her understanding of the material.

During this time, even further practice is available in the form of an online quiz using the eLearn course site. These quizzes are for practice only and are not included in the student's course grade in any way. The students are allowed to take the quiz as many times as they wish. A total of 42 questions have been developed that fall into one of ten different categories. The categories were established to include all aspects of the process including linear interpolation, unit conversion, understanding the state/phase of the substance, using and understanding the quality, and using all of the Property Tables listed previously. Each time the student takes the quiz, one question is randomly selected from each category meaning that there are only ten questions selected for each quiz. Because the questions are selected randomly and the answer choices are randomized each time the quiz is taken, the quizzes are somewhat unique with each attempt. Feedback is also provided for each problem which illustrates the correct solution. This quiz is made available to the students when this topic is first introduced and remains available until the final component is completed, typically 1.5 weeks.

The final component is a game that is played during one class meeting at the end of this portion of the course. Each student receives a game board containing a grid that looks somewhat like a BINGO card, see Figure 4. Along the top the grid is labeled with property states, and down the left side the grid is labeled with different substances. Unlike a BINGO card, all cards are the same. The goal of the game is not to achieve a BINGO, but is to gain bonus points for the course homework grade, which is 20% of the semester grade in the course.

Microsoft PowerPoint is used to present mini-problems to the class where the substance and two property values are given, see Figure 3. Each mini-problem then asks for an unknown third property value for that substance as defined on the slide. The students are told that they must also name the state for each mini-problem; this is not shown on the PowerPoint slides. The first student to believe that he/she knows the answers raises their hand and is given the opportunity to give his/her answer. If the answer is correct, then the student receives his/her bonus credit and is no longer eligible to answer. Only accepting one correct answer from each student during the class meeting allows every student to have a chance and keeps a small group of students from earning all of the available bonus points. The students are also encouraged to help other students once they have earned their points for the game. Again, this assistance will help both students in a similar manner to allowing them to work in small groups for the assignment discussed previously. If the first student who is called upon gives an incorrect answer, then the professor waits to see if another student will attempt to answer correctly. In the case where a sufficient amount of time passes with no correct answer, the professor reveals the answer and discusses it with the class. In this case, no student will be awarded bonus points. This tends to happen most frequently with the Compressed/Subcooled Liquid phase/state problems.

R-22:
p = 600 kPa
x = 1
u = ?

Figure 3: Example Mini-Problem for BINGO game.

ME 3210 – Thermodynamics

BINGO

	Compressed Liquid	Saturated Liquid	Saturated Mixture	Saturated Vapor	Superheated Vapor
H_2O					
R-22					
R-134a					
Ammonia					
Propane					

NOTE: For full credit all answers must include appropriate units.

Figure 4: Game Card for Thermodynamics BINGO.

Similar to the online quiz, the mini-problems are designed to test all aspects of the process listed previously. Students are made aware that the game will incorporate the same topics as the assignments and online quiz and that the amount of bonus points to be earned will be dependent on their ability to perform these tasks in a timely manner. There are 25 mini-problems, one for each grid space on the game card. Before the game begins, students are made aware of this fact. This tells the students that if they try to place a second mini-problem solution into an already filled grid space, then something is wrong and they need to try again to get the correct answer. The number of mini-problems that are completed each semester varies. Only one class meeting will be used, so the number of mini-problems completed is a function of the amount of preparation by the students. If it takes longer to get to an answer, then fewer mini-problems will be completed and fewer students will receive the bonus credit.

At the end of the class meeting, a complete list of the mini-problems is distributed to the class. The students are allowed to complete the game card as a homework assignment for additional bonus credit. If a student records the answers as the game is played, then this becomes free bonus points. If they do not record the answers, then they must either redo the problems or forego the opportunity for the bonus points. Allowing the students to complete the assignment for homework also has an equalizing effect. That is, the students who do this receive the majority of the credit. The amount of credit given to the students who get an answer correct in the class meeting is significant, but considerably smaller than the bulk of the credit given for completing the assignment. Again, the idea is to give the student sufficient practice to master this skill before moving onto other course material.

Considering that the credit earned in the game is bonus credit, and that the online quiz presented previously is not counted for credit, there is one final assignments for the students to prove that they have mastered the skill of setting the state and retrieving property data. This assignment is another online quiz that utilizes the same set of questions for each student. However, the questions are randomized and then the answers for each question are randomized so that each student's quiz will appear somewhat different. This is intended to present an obstacle against cheating amongst the students in the class. Again, the questions for the required online quiz are designed to incorporate all aspects listed previously. This assignment is required and counted as part of the homework grade.

The classroom activities, assignments, and lessons presented here are rigorously designed to help the students in fixing the state and retrieving property data that will be critical in achieving accurate results in Thermodynamics I and II. Their implementation has been carefully crafted to motivate the students to learn this skill well, and in a timely manner. It is unfortunate that obtaining quantitative assessment of the techniques presented here is very difficult to achieve. This is due to the restriction that the exam questions are typically not designed to isolate the skill being enhanced, and because the implementation of the interventions was gradual which did not allow for a control group to analyze the overall effect of all of the interventions described. One potential limitation to implementing these techniques into another course is that they are specifically designed to affect small component of the course, obtaining a certain skill.

The use of the game grid, for example, requires that the focus of the skill, or course component, involve categories that can be structured into a grid type of organization. Another potential limitation to implementing these techniques in other courses is in the timing. This course implementation is done in a format where the class meets three days a week, for 55 minutes each day. Other formats, such as single or two day formats, would need to make necessary adjustments. Current trends in Engineering Education are putting more emphasis on the student's ownership of learning and on more active learning techniques. The activities and assignments discussed here are incorporating both of these concepts. The students have a very positive reaction to playing a game in class, and are challenged to do their best not just on this skill but throughout the course as a result.