

**AC 2008-1803: PROMOTING STUDENT ENGAGEMENT IN  
THERMODYNAMICS WITH ENGINEERING SCENARIOS (YEAR 2)**

**Patrick Tebbe, Minnesota State University-Mankato**

**Stewart Ross, Minnesota State University, Mankato**

**Michael Ostendorf, Minnesota State University-Mankato**

**Scott Cray, Minnesota State University-Mankato**

# Promoting Student Engagement in Thermodynamics with Engineering Scenarios (Year 2)

## I. Introduction

Many thermo-fluids courses are taught with traditional teaching methods and textbooks. Thermodynamics, in particular, is prone to elicit a negative impression from students "who perceive the subject as dry and abstract."<sup>1</sup> While there has been progress in recent years, there are still limited visual aids depicting actual equipment or industry settings. Even though the topics covered often have a real-world basis they are generally simplified and only offer a superficial impression of industry applications. This is especially true in the first thermodynamics course which is theory heavy. The result is that many students have excessive difficulty with the subject and do not develop a "feel" for the topic or the associated real-world equipment<sup>2,3</sup>. Felder et al. have summarized this best by stating that without student interest or a belief in the need to learn the material, a course "stimulates neither interest nor motivation to learn. The fact that many students in these courses appear apathetic and do poorly...should not come as a surprise".<sup>4</sup> The relevant educational research and literature is clear in the belief that greater student impact, understanding, and retention can only be achieved with greater student engagement<sup>5</sup>.

Through a NSF Course, Curriculum, and Laboratory Improvement (CCLI) grant, supplementary course material for thermodynamics is being designed for dissemination/production in an electronic format and for use with standard thermodynamic textbooks on the market. The material will include descriptions of real-world settings, each with several skills based (i.e. standard homework) and design-based problems specified. The combination of real-world setting and problems (along with associated background information and solutions) is referred to as an "Engineering Scenario". Each Engineering Scenario is based on a real-world engineering facility in a form similar to, but expanded from, a case study. The scenario will include extensive background information on the facility history and purpose, and information on the engineering personnel responsible for the facility. For each scenario a series of problems are being developed. These problems will take one of three possible forms: skill-based problems, short design problems, and large design problems. While each scenario will center around one engineering facility, the topics covered by these problems will span several chapters or topics in a traditional textbook. This will allow problems to be used from a single scenario throughout the semester. It is expected that a greater sense of cohesion and continuity in the material will therefore be generated. In this update material will be highlighted that has been added over the last year and aspects which are under development will be described. This includes several ideas which were generated through student focus groups.

## II. Description of the Scenario Concept

A Scenario is generated from a combination of narrative descriptions, skill-based problems, and design problems. Skill-based problems differ from existing textbook problems in that they are written in the context of the existing facility instead of being written in generic terms. By basing

these problems on a specific and well-researched facility the instructor's knowledge is fortified and the student's interest can be exploited to encourage greater engagement. Even if a student is not motivated to research beyond the problem statement the added visual information and the move from a generic problem to one with its' own identity is expected to increase student engagement and subsequently performance. As with skill-based problems design problems are written in the context of the scenario environment and will take into greater consideration the normal tasks required of an engineer there. All points of the description, data, and objectives are being taken from the real-world facility.

To test the Scenario concept, material is being generated around the engineering facilities of Minnesota State University Mankato (MSU), located in southern Minnesota. The campus consists of approximately sixteen academic buildings, three dormitories, and supports over 12,000 students. To address the University's heating and cooling needs the Facilities Department maintains a centralized facility plant and equipment distributed across campus. Equipment at the facility plant has expanded over the last two decades to include many processes which can be used to relate thermodynamic theory to the real world. This includes a heating system with four boilers supplying steam rates from 7,000 lb/hr up to 50,000 lb/hr, three water chillers with a total capacity of 3200 tons for air-conditioning, three dual-cell cooling towers, two emergency diesel generators which can produce 1200 kW, and three stand-by diesel generators which can produce 6 MW. Additional details on the system specifications can be found in previous publications<sup>6</sup>. There are also several case study or design problem possibilities, which demonstrate both good and bad design. These include a 434 kW cogeneration system which was installed but never functioned properly, the possible addition of an additional chiller unit, and expansion of the steam and chilled water distribution system to accommodate additional construction. This construction includes a 70,000 ft<sup>2</sup> science addition with once-through air handlers and enthalpy wheel heat recovery.

Over the course of Summer 2006 undergraduate research assistants and faculty researched the campus equipment and designs. Photographs were taken of the equipment, interviews were held with plant personnel, and plant data was reviewed for many operational aspects. From this a narrative was created explaining all of the major systems on campus and how they operate. Pictures and schematics of the systems were included as well as links to manufacturers' websites and specification sheets. The initial Scenario was then built from this information. Due to the large amount of cross referenced information which can be included in material of this sort an electronic format is currently being used. However, student focus groups indicated that students did not always favor electronic materials and generally show a preference for a traditional hard bound text. Taking this into consideration care has been taken to structure the Scenario material so that all problems and text sections can be opened in an alternative pdf format for printing. Additional information on the general framework of the material and the user interface can be found in Tebbe et. al.<sup>6</sup>.

### **III. Formative Assessment Results**

A variety of assessment techniques are being used to assess the material<sup>7</sup>. These include pre- and post-concept inventories, periodic quick surveys on engagement, correlations with course and test grades, and student focus groups. In terms of changes to the format or content of the

material the focus groups have been crucial. Student attended the focus groups on a voluntary basis. The groups met with an assessment coordinator from outside of the engineering departments to avoid instructor induced biases. Each focus group was asked a series of predetermined questions dealing with engagement in the course, format of the course, and the Engaged in Thermodynamics material. The assessment coordinator was then free to ask follow-up questions based on the student's responses.

Overall the initial assessment was very positive. Students felt that the Scenario problems were more interesting than normal textbook problems. The Scenarios gave a sense of steps to take in the real world and forced them to investigate things. The problem format helped review information learned so that concepts were understood better. Finally the material helped students see the big picture by grouping ideas together. In terms of engagement, the online material was found to be useful in that it is different and helps develop engagement. In contrast, students stated that typical homework problems help focus engagement.

To compare to traditional textbook formats several questions were asked about the differences in using the textbook and Scenario material. The textbook was said to be well-organized and good for review if stuck with a question. Students stated they do not read it cover to cover, reading the textbook seemed to be a last resort. The text was not a motivating force for them. The textbook was seen as needed but it was nice to move beyond that to ideas that were less abstract. Students expressed a like for things that apply to real world situations, including design projects. However, students did express the opinion that there may be some online materials which are better than the new Scenarios. Specifically it appeared that students were looking for more information to answer the questions of "how" and "why" than were provided with the Scenarios. For instance, while students expressed a positive reaction to the increase of equipment photographs they also expressed a desire for more schematics showing how things worked.

#### **IV. Changes Made to the Beta Version**

Based on the formative assessment data, several modifications were deemed necessary. Over Summer 2007 two undergraduate research assistants assisted with a complete editing of the material to address several modification issues. This included a rewriting of the narrative sections with the inclusion of additional information in some areas, such as stand-by diesel generators. Additional links were also placed throughout the narrative allowing students to move more seamlessly between related topics (Figure 1).

Students indicated that some of the material was worded in a confusing manner. Therefore, the skill-based (i.e. homework) problems were reworded to eliminate confusion and additional diagrams were added. An interesting development aspect that came out of this was the role of developer perspective. Instructors will often assume that students have a certain knowledge or understanding of the physical world which may in fact not be there. This increases student frustration and can limit their progress. The intention of this project was to make use of undergraduate students for the material development so that they could act as "assumption checkers". However, barely two weeks into the summer work the undergraduate assistants had become so familiar with the thermodynamics material that they started to fall into the same trap, even to the point of uttering the phrase "but they should understand that." Feedback during

actual student use is therefore critical to improving the material. However, the material is too large to completely evaluate in one semester's work. Attempts are being made during the Spring 2008 Applied Thermodynamics course to recruit additional student reviewers from the class to address this.

Students suggested that videos of the equipment working would be interesting and would aid in engagement. Similarly, a concern was expressed that the photographs of plant equipment did not provide a good size perspective. This was expressed early in the assessment when students started complaining that the problems would make more sense if they could visit the Facilities plant. Since the intent of the material was to convey a greater realism this was initially disturbing. To address this several of the plant photographs were retaken and were specifically staged to include items giving a size perspective (typically a student as seen in the right picture of Figure 1). Walk through videos of the plant were also added for the boiler room and the chiller room (Figure 2). These videos allow the students to get a better perspective of the size and location of all of the equipment. Audio commentary was also provided on the video by the undergraduate research assistants.

Lastly, during the initial assessment of the material there had not been sufficient time to develop sufficient design oriented problems for the first thermodynamics course (referred to as "Plant Assignments" in the material). Several problems which were more open-ended were, therefore, added to the first course topics. Keeping in mind that students at this level may not have had much exposure to design procedures or higher levels of cognitive thinking, different types of problems have been created which range in difficulty. For instance, students were asked to evaluate the use of biodiesel versus diesel in the campus standby generators. The calculations for this problem are fairly straightforward, however; several assumptions need to be made and the students are encouraged to consult the provided background material on the generators. In addition, the students are asked to comment on the environmental impact of the two fuels. This required them to do a small amount of independent research and then make conclusions. However, it did not require much of them at upper most cognitive levels, for instance Synthesis and Evaluation in Bloom's taxonomy.

## **V. Additions to the Material Based on Feedback**

There were also several aspects added to the material which had previously not been considered. These resulted from a combination of assessment feedback and working closely with the undergraduate research assistants. For instance, feedback from students indicated that even with all of the information the "big picture" still was not getting across. To address this several things were added. For each homework problem a "Reality Check" link was provided in the problem statement (Figure 3). This link takes the student directly to the location in the Background information that described the real-world aspects of the problem. This made the material easier to use and navigate and promoted more student investigation into the problem background.

For each major homework section, such as "Control Volume Analysis", an introductory page was also added before students could view the actual homework problems. This page provided a brief definition of the topic, a link to glossary terms, hints for solving the problems in that section, and newly developed support material (Figure 4). For instance, the undergraduates

working on the project commented that after you take both semesters of thermodynamics you realize why the things you initially covered were important. However, hearing from your instructor that this will be the case may not be the best way to convince students. Therefore, several student videos were produced which included commentary from students who had already taken both thermodynamics courses, and in some cases had interned in related fields. In the videos the student volunteers commented on the things they were interested in or engaged them in the courses and their impression of the topic after the courses. Feedback from students indicated that these videos were a good idea but that they had little impact because the students already knew all the people in the videos and talked to them on a regular basis about the thermodynamics course.

Another addition which was largely spearheaded by the undergraduate research assistants was the addition of example problems. Rather than create static examples similar to a textbook a much richer format was chosen. The problem statement itself was provided in text format, however; the solution for the example problem was presented as a short video. The video included initial captions of the actual plant equipment in the problem and then moved to a student actually solving the problem (Figure 5). This allowed the students to provide commentary on how they were solving the problem and what their approach was.

## **V. Conclusions and Future Work**

The modified material was used in the introductory thermodynamics course during Fall 2007. Full analysis of the quantitative assessment data is still ongoing and the material has yet to be reused in the applied thermodynamics course. However, several general comments can be made based on student feedback and focus group information. The students indicated that the changes were positive improvements. The Engaged in Thermodynamics material was described as giving a 'richer perspective' and 'motivating.' The addition of more projects was seen to create greater student involvement. Finally, the additional student videos were seen as a positive, however, with diminished impact. Since the students in the videos were ones the class students were already talking to about engineering and thermodynamics it was felt the full impact was diluted.

Besides the ongoing assessment there are still items of material development underway. While several design problems have been created the current activity involves creating industry modeled solutions to these problems. Several engineering and design firms are being contacted to provide input on how each design problem would be addressed on the job. We are also gathering information on real world aspects which it is not feasible to address in the design problems. This information will be formatted and included with the instructor's package. It may then be used as the instructor deems appropriate (in class discussion, hand out after assignment is complete, or to be given out with the assignment as a guide). Lastly, as part of the dissemination portion of the proposal a workshop is being planned to provide information on the finished product. This workshop was to be held during the summer of 2008 and will involve inviting appropriate guests to campus to hear information on the new material, view the material, interact with some students who have used the material, and discuss their opinion of it.

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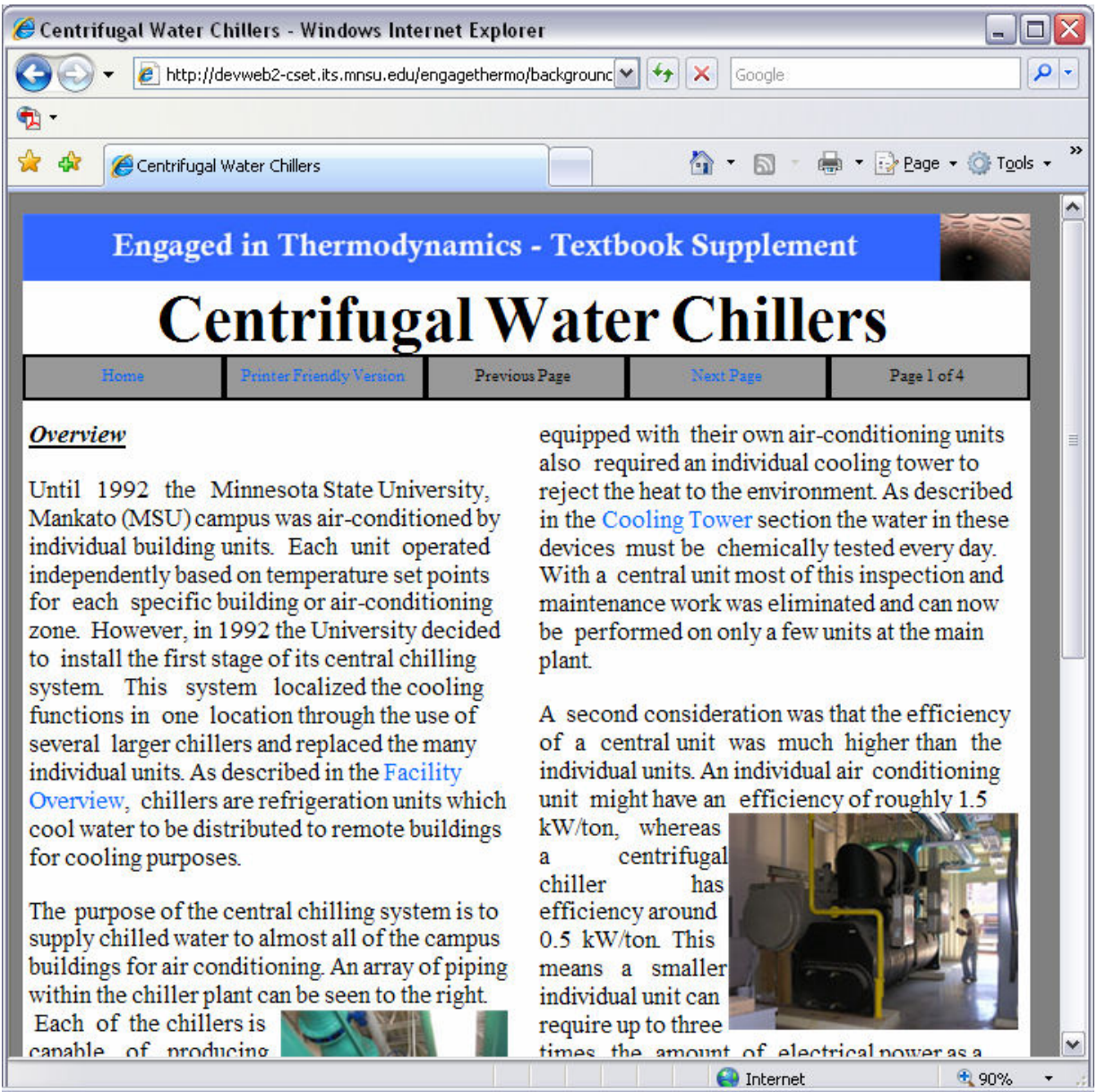


Figure 1: Example of reformatted background narrative. Perspective aspects of equipment and links to other sections have been added.





Figure 2: Portion of a walk through video of the boiler room showing the controls for one boiler.

Control Volume Analysis - Windows Internet Explorer

http://devweb2-cset.its.mnsu.edu/engagethermo/Assignments/Control\_Volum...

Control Volume Analysis

## Control Volume Analysis

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**C8) Consider the MSU boiler and cogeneration turbine together as a system (as shown below). The flow rate through the system is 22,500 lb/hr with an output quality of 97.6%. The boiler supplies 21.26 MBTUH of heat transfer to the water. The inlet conditions of the boiler are a pressure of 150 psig and temperature of 282 °F and the outlet pressure is 50 psig. In order for the Director of Facilities to determine if the turbine is cost effective the amount of work produced must be known. Determine the amount of work in kW produced by the turbine and the turbine inlet temperature in °F. (Reality Check) (Full Page Version)**

$\dot{Q}_i = 21.26 \text{ MMBtuh}$

Boiler

$\dot{m} = 22,500 \text{ lbm/hr}$   
 $T = 282^\circ\text{F}$   
 $P = 150 \text{ psig}$

Cogen Turbine

$\dot{W}_t$

$x = 97.6$   
 $P = 50 \text{ psig}$

Cogeneration Schematic

**C9) Chilled water exits the evaporator of one of the MSU campus centrifugal chillers at 44°F. Liquid water**

Done | Internet | 100%

Figure 3: Example of a skill-based problem with updated figures. Notice the link in the problem statement to the “Reality Check.”

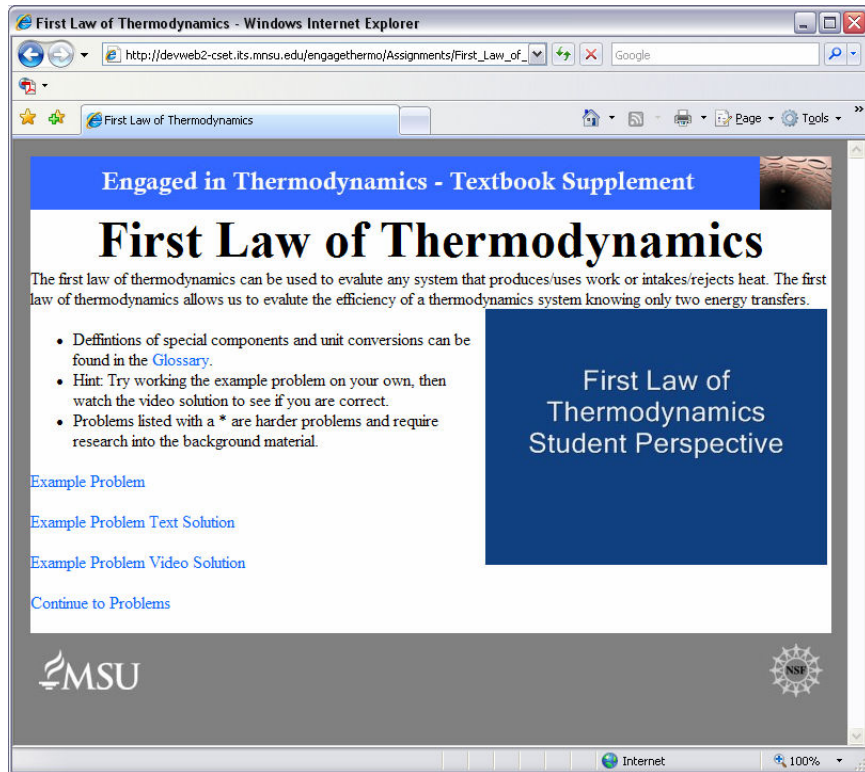


Figure 4: Example of new interface for problem sections.

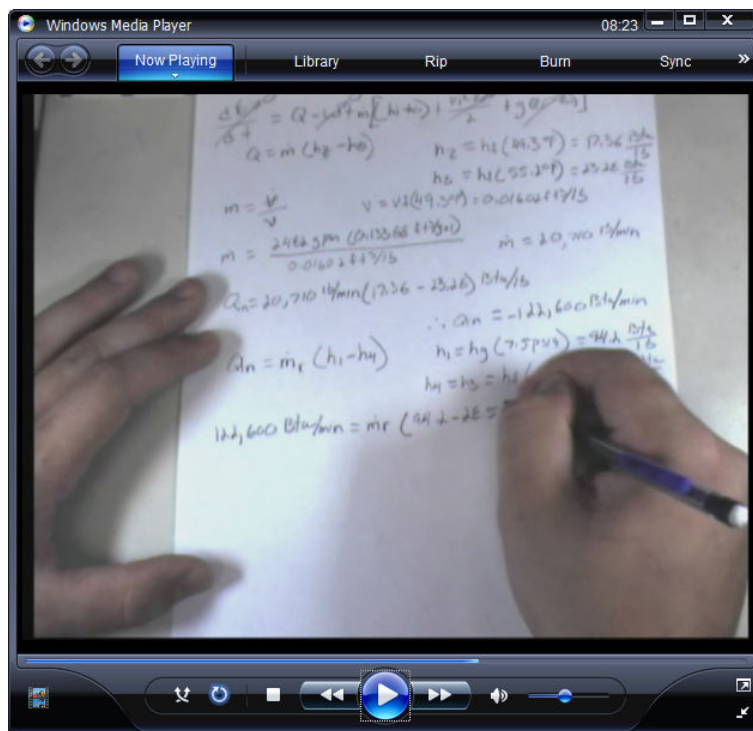


Figure 5: Example of a student modeled solution to a skill-based (i.e. homework) problem.