AC 2011-1445: ENGAGED IN THERMODYNAMICS ADDRESSING THE STUDENT TO LEARNING MATERIAL INTERFACE

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Engaged in Thermodynamics – Addressing the Student to Learning Material Interface

I. Introduction and Project Background

This paper will discuss a current NSF-CCLI Phase 2 grant that addresses improvements in student pedagogy and educational materials for the engineering thermodynamics curriculum by completing development of the concept of an “Engineering Scenario”. Engineering Scenarios are textbook supplements based on actual engineering facilities and equipment. They expand on the case study concept by including skills-based problems that can be used in place of traditional homework problems but written in the context of the real-world environment, as well as additional design problems based on design methods and actual solutions at real facilities (Table 1). Accompanying supplementary and background information promotes increased inquiry-based or student-centered learning, better addresses student real world expectations, and leads to an increase in overall student engagement.

It should be noted that use of these expanded problems does not imply using class time to cover the added material. There is great pedagogical flexibility in the approach allowing varying levels of use by the faculty member. The connection to reality is achieved by formulating the problem within the scenario environment. While a professor could directly use or try to cover the wealth of available information connected to the problem, it is not necessary or expected. The intention is for the student to select what they would like to explore and direct their own learning of the additional material. Subsequently these problems could be used in place of a normal textbook problem without any additional time required in lecture. Even if a student is not motivated to research beyond the problem statement, benefits will still result. As an example, for thermodynamics an existing power plant might be chosen for the scenario. Whereas students are generally told “a turbine exists at these conditions,” here they will be told what type of turbine it is, what the turbine’s purpose is, and where the operating conditions come from. The added visual information and the move from a generic problem to one with its’ own identity has been shown during Phase 1 to increase student engagement and subsequently performance.

This type of material would be infeasible for traditional paper textbooks due to space and format limitations. For this reason an electronic format based around a website design was chosen for the Phase 1 work. The original grant allowed for the development and repeated formative assessment of a single scenario. To test the Scenario concept, material was generated around the engineering facilities of Minnesota State University Mankato (MSU), located in southern Minnesota. The product was titled “Engaged in Thermodynamics” and was evaluated over two years in courses at MSU. Following extensive formative assessment several student guided modifications were made to the original format. Additional links and cross-links were placed throughout the narrative allowing students to move more seamlessly between related topics. Additional videos, audio commentary, and hyperlinks in homework problems were also added.

Table 1: Elements of an Engineering Scenario

Description

- Narrative of facility purpose, location, and history (with emphasis on interesting "stories")
- Description of all major equipment (images, specification sheets, key parameters)
- Personnel interviews (presented as short videos and narrative)
- Walk through videos of one or more similar facilities

Problems

- Skill-based Problems including "Reality Check" links to Description data (approximately 50 problems spanning several topics)
- Short Design Problems (3-5 problems)
- Large Design Problems including descriptions of industry solution (3-5 problems)
- Student modeled solutions (variable number of student narrated videos)

During the last year it has become evident that rather than focus on the creation of additional narrative and homework material, that structural issues with the material needed to be resolved first. These issues revolved around two aspects; readability of the material and learner interface. Student feedback has consistently indicated that some problem statements were confusing. While this can be an issue with any textbook development it is complicated by the heavy use of industry terms the student may not be familiar with in the real world descriptions. Engineering students were employed to do the initial document hypertext formatting and a nice product was produced. However, a sharper more professional looking final product is desired for the fully developed project. Student feedback has indicated that several aspects of the material were under-utilized because of interface formatting issues, not due to student opinion or engagement reasons. This paper will highlight the current work in both of these areas.

II. Readability Studies

The reading difficulty of a material is known as its readability. Two forms of readability analysis were used to evaluate the Engaged in Thermodynamics material, as well as several thermodynamic textbooks. These were the Flesch-Kincaid grading level and the Flesch Reading Ease Test. The methods are based upon sentence length and the number of syllables per section of text. The methods strictly address level of reading and do not address prior knowledge of the material or reader comprehension.

The Flesch-Kincaid grading level rates a text on a U.S. school grade level. A score of 6.0 implies that a sixth grade student can understand the document. A score of 13.0 corresponds to a freshman level in college. This score is based on an average sentence length and average number of syllables per word. The formula for the readability score is given by:

$$(0.39 \times ASL) + (11.8 \times ASW) - 15.59 \qquad (1)$$

where ASL is the average sentence length (the number of words divided by the number of sentences) and ASW is average number of syllables per word (the number of syllables divided by the number of words).[1]

The Flesch Reading Ease Test rates a text on a 100-point scale. The higher the score, the easier it is to understand the text. The score is based on average sentence length and the average number of syllables per word. The formula for the Flesch Reading Ease score is given by:

$$206.835 - (1.015 \times a1) - (0.0846 \times v1) \qquad (2)$$

where a1 is the average sentence length and v1 is the number of syllables in the text being analyzed. A score of 60-80 represents a reading level from 8th to 9th grade. A score of 50-60 represents a 10th and 12th grade reading level. A score of 30-50 represents a reading level for an undergraduate, and a score below 30 is for graduate level reading. It is recommended for most standard texts that the score should be between 60 and 70.[2]

A third method of evaluating readability is to examine the use of passive sentences. The use of a passive voice can affect the clarity of material. A passive voice can be defined as one where the object of an action is made into the subject of a sentence. On the other hand, an active voice is one that specifies “who or what is doing the action”.[3]

Initially, students were asked to identify several paragraphs from the Engaged in Thermodynamics material that they thought were “Good” and “Bad” paragraphs, based on their reading of them. These paragraphs were then evaluated using the methods described above (Tables 2 and 3).

Based on this initial data, solid conclusions were difficult to make. In general it can be said that all of the sections were at an appropriate reading level. However, indications are that the “Bad” sections have a better Flesch Reading Ease test score and a lower Flesch-Kincaid grade level than the “Good” sections. The number of passive sentences is also slightly larger for the “Bad” sections than the “Good” ones. It was clear that additional information was needed to fully understand what they ratings imply for university thermodynamics.

The second phase of study moved to several thermodynamic textbooks on the market. Like most engineering textbooks, much of the text was broken up by equations, examples, and figures. These additions create difficulty in readability assessment because readability does not include the structure of the text. Therefore, the textbooks were reviewed to find appropriate sections for readability analysis. For each textbook a section was selected from the same topic; introduction to the second law of thermodynamics. The readability scores obtained are shown in Table 4. The partitioned average is the average obtained by summing the readability scores from each paragraph and dividing by the total number of paragraphs in the section. The average is the readability of each section as a whole.

Table 2: Readability tests applied to "Good" text sections from the Engaged material.

	Para. 1	Para. 2	Para. 3	Para. 4	Para. 5	Para. 6	Para. 7	Para. 8	Para. 9	All
Passive Sentences	14%	50%	50%	63%	25%	33%	0%	0%	12%	32%
Flesch Reading Ease	18.3	45.4	65.7	52.2	35.9	33.8	30.3	40.4	41.4	42.2
Flesch-Kincaid Grade Level	15.9	12.1	8.5	10.0	13.0	13.4	12.8	12.8	11.6	11.9

Table 3: Readability tests applied to "Bad" text sections from the Engaged material.

	Para. 1	Para. 2	Para. 3	Para. 4	Para. 5	Para. 6	Para. 7	Para. 8	Para. 9	Para. 10	All
Passive Sentences	46%	50%	0%	33%	20%	42%	100%	100%	11%	25%	42%
Flesch Reading Ease	46.3	59	64.0	60.7	41.8	50.9	66.2	50.0	51.2	46.0	53.3
Flesch-Kincaid Grade Level	11.5	9.5	8.1	8.8	13.1	9.3	7.8	12.1	9.6	11.4	10.1

Table 4: Readability results from three undergraduate engineering thermodynamics texts.

Textbook #1

	Partitioned Average	Average
Flesch-Kincaid	13.94	14.0
Flesch Reading Ease	39.02	37.9

Textbook #2

	Partitioned Average	Average
Flesch-Kincaid	13.725	15.7
Flesch Reading Ease	37.38	24.8

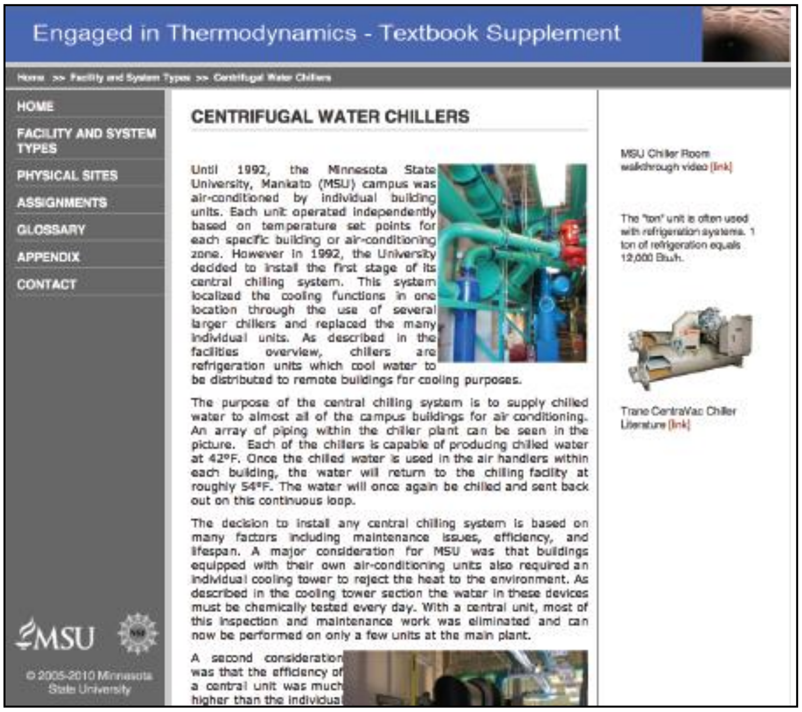
Textbook #3

	Partitioned Average	Average
Flesch-Kincaid	11.52	11.7
Flesch Reading Ease	47.67	47.7

For the sections and textbooks chosen, the Flesch-Kincaid results ranged from 11.7 to 14. The Flesch Reading Ease results ranged from 37.9 to 47.7. Comparing the Engaged in Thermodynamics material to the textbooks, the results would indicate that the new material is easier to read than the textbooks. However, qualitative indications from students working on this project would seem to indicate that the number of passive sentences is a better indicator of whether a student likes or dislikes a reading selection. At this time, the results are preliminary and the number of passive sentences has not been evaluated for the textbooks.

III. Learner Interface

A major undertaking of the Phase 2 grant is to expand the material to include information on multiple sites, or scenarios. This will dramatically increase the total amount of information, the types of equipment and facilities discussed, the amount of multimedia information present, and the number of student problems included. Organization of the material, therefore, becomes a more daunting and complicated task. Through a number of feedback sessions with students who were in, or had completed, engineering thermodynamics several interesting facts about the original material were discovered. Originally the material was sized to fit on one screen with navigation buttons along the bottom of the page. However, with changes in web browsers and monitors many students were not seeing these tabs (as they were off the screen). Since the students did not immediately see the tabs the likelihood of them using them was greatly diminished. As seen in Figure 1, the updated material has moved the main navigation buttons to the left hand side where they are readily visible.



CENTRIFUGAL WATER CHILLERS

Until 1992, the Minnesota State University, Mankato (MSU) campus was air-conditioned by individual building units. Each unit operated independently based on temperature set points for each specific building or air-conditioning zone. However in 1992, the University decided to install the first stage of its central chilling system. This system localized the cooling functions in one location through the use of several larger chillers and replaced the many individual units. As described in the facilities overview, chillers are refrigeration units which cool water to be distributed to remote buildings for cooling purposes.

The purpose of the central chilling system is to supply chilled water to almost all of the campus buildings for air conditioning. An array of piping within the chiller plant can be seen in the picture. Each of the chillers is capable of producing chilled water at 42°F. Once the chilled water is used in the air handlers within each building, the water will return to the chilling facility at roughly 54°F. The water will once again be chilled and sent back out on this continuous loop.

The decision to install any central chilling system is based on many factors including maintenance issues, efficiency, and lifespan. A major consideration for MSU was that buildings equipped with their own air-conditioning units also required an individual cooling tower to reject the heat to the environment. As described in the cooling tower section the water in these devices must be chemically tested every day. With a central unit, most of this inspection and maintenance work was eliminated and can now be performed on only a few units at the main plant.

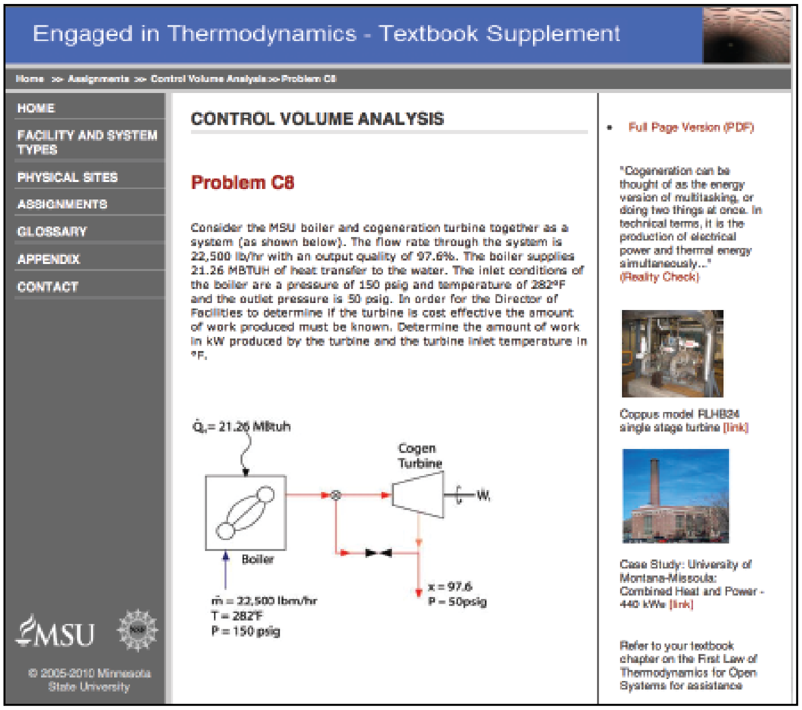
A second consideration was that the efficiency of a central unit was much higher than the individual

MSU Chiller Room walkthrough video [link]

The "ton" unit is often used with refrigeration systems. 1 ton of refrigeration equals 12,000 Btu/h.

Trane CentraVac Chiller Literature [link]

Figure 1: Updated narrative section with navigation buttons on the left.



CONTROL VOLUME ANALYSIS

Problem 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.

- Full Page Version (PDF)

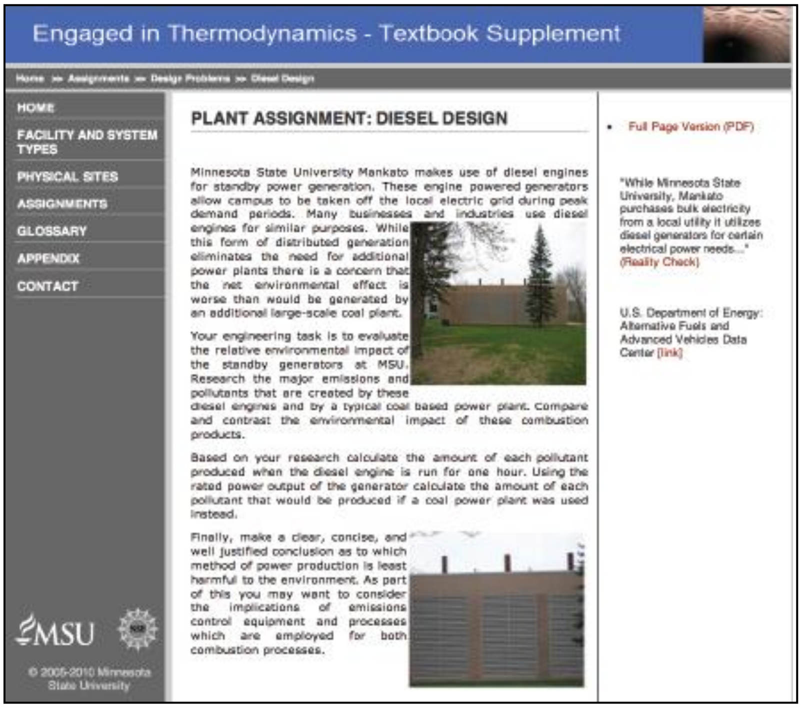
"Cogeneration can be thought of as the energy version of multitasking, or doing two things at once. In technical terms, it is the production of electrical power and thermal energy simultaneously..." (Reality Check)

Coppus model RLHB24 single stage turbine [link]

Case Study: University of Montana-Missoula: Combined Heat and Power - 440 kWe [link]

Refer to your textbook chapter on the First Law of Thermodynamics for Open Systems for assistance

Figure 2: Updated problem assignment page with reality check on right side bar.



PLANT ASSIGNMENT: DIESEL DESIGN

Minnesota State University Mankato makes use of diesel engines for standby power generation. These engine powered generators allow campus to be taken off the local electric grid during peak demand periods. Many businesses and industries use diesel engines for similar purposes. While this form of distributed generation eliminates the need for additional power plants there is a concern that the net environmental effect is worse than would be generated by an additional large-scale coal plant.

Your engineering task is to evaluate the relative environmental impact of the standby generators at MSU. Research the major emissions and pollutants that are created by these diesel engines and by a typical coal based power plant. Compare and contrast the environmental impact of these combustion products.

Based on your research calculate the amount of each pollutant produced when the diesel engine is run for one hour. Using the rated power output of the generator calculate the amount of each pollutant that would be produced if a coal power plant was used instead.

Finally, make a clear, concise, and well justified conclusion as to which method of power production is least harmful to the environment. As part of this you may want to consider the implications of emissions control equipment and processes which are employed for both combustion processes.

- Full Page Version (PDF)

"While Minnesota State University, Mankato purchases bulk electricity from a local utility it utilizes diesel generators for certain electrical power needs..." (Reality Check)

U.S. Department of Energy: Alternative Fuels and Advanced Vehicles Data Center [link]

Figure 3: Updated design problem specification.

With so much additional information to be added and the possibility of so much cross linked information, being able to back track through the material was a new need. The updated material has added a navigation "history" at the top of each page (seen in Figures 1-3) which shows each major section which is passed through from the main page to the current page.

A strong suggestion from the students was to make the site look more like Wikipedia. It was eventually determined that this referred to the side bar on the right hand side, which typically holds links to related information. A right hand side bar was added to all pages. This served an additional use for problem pages. Previously each problem statement had a link called "Reality Check" which takes the student to the related narrative section. Students expressed a desire to preview this information before clicking the link. Therefore, the Reality Check links were moved to the right side bar with the first sentence or two of the narrative included (Figure 3).

IV. Future Work

During the next year of this grant there will be several focuses. A major undertaking will be to continue gathering information on additional scenarios. This involves constructing a number of new student problems which must be tested for validity and clarity. Site assessment procedures are being put in place and potential assessment sites are continually being sought. However, work will continue on the issues of readability and learner interface. While there is qualitative indication of good and bad sections in the Engaged in Thermodynamics material, there is no student correlation to the readability tests used. Closing the gap between student impression and the current date, both for the Engaged material and the textbooks, will help explain what the values are indicating. For the learner interface, student feedback and focus groups will continue to be conducted. Researchers and educators in many areas are currently grappling with the pedagogical issues of e-books and online material. The current work is expected to both contribute and benefit from these efforts.

Bibliography

1. Flesch, R. A New Readability Yardstick. *Journal of Applied Psychology* **1948**, *32*(3), 221-233.
2. Flesch, R. *The Art of Readable Writing*. New York: Harper and Row, 1949.
3. Class handout. http://www.unc.edu/depts/wcweb/handouts/passivevoice.html

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