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Engaged in Thermodynamics – Learning What We Don't Know

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Abstract

This paper will discuss a near completion NSF-CCLI (TUES) grant that addresses improvements in student pedagogy and educational materials for the engineering thermodynamics curriculum. The project is developing 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. This paper will highlight the final version of the Engaged material. This will include key points of the assessment data and focus group results obtained since last year. A secondary purpose of the paper will be to discuss how this Phase 2 research has spawned several other pedagogical research questions (i.e. possible new Phase 1 research). Three specific areas will be highlighted: 1) a compare and contrast study of engagement and motivation in engineering, 2) a study of how students actually use electronic study materials, and 3) a readability assessment of current textbook materials in relation to student preferences.

I. Background

The Engaged in Thermodynamics material has been described in several previous publications [1,2]. It was conceived to address several challenges in engineering education, specifically in the area of thermodynamics. At the time traditional textbooks and classroom formats were found to elicit a negative impression from students "who perceive the subject as dry and abstract" [3]. Students have difficulty with the subject and do not develop a "feel" for the associated real-world equipment [4,5]. The Engaged material was designed to help overcome this by providing supplementary material based on real world facilities in a format similar to a case-study. However, the material would go beyond the case-study format and include numerous skill based problems, similar to traditional textbook problems, based on the facilities. By using the Engaged problems in place of textbook homework student interest could be fostered in a traditional "chalk and talk" classroom but the format and extent of the material would facilitate a variety of pedagogical approaches.

The material takes elements of textbooks, case studies, and other experiments in electronic learning. 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. [6] The format of the material is described as an "Engineering Scenario". The components of each scenario are listed in Table 1.

A NSF CCLI Phase 1 project explored development of a single facility scenario and provided several useful assessment results [7]. Assessment demonstrated that students expect to be exposed

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 related background information
- Short Design Problems (minimal calculations required)
- Large Design Problems including descriptions of industry solution (open-ended solutions)
- Student modeled solutions (student narrated videos)

to real world content and that traditional textbooks do not fulfill this expectation. Results also showed that there was a direct link between student engagement and final grade. Use of the Engaged in Thermodynamics material was shown to increase student engagement and better satisfy their content expectations. Based on this a Phase 2 grant was awarded for full development of the material.

II. Description of Material

The Engaged in Thermodynamics material is based on a set of physical locations and the associated systems. Each system is then broken down into the multiple components that make up the systems. Since each location may have multiple systems and multiple systems may use the same components there is a large amount of overlap in the topics. Therefore, the material was designed so that the maximum amount of cross-linking between topics could be achieved. The material was designed in a web based format which allowed the addition of photos, diagrams, animations, and videos. All skill based problems (i.e. homework) and plant assignments (i.e. open-ended problems) were provided with pdf printing options. A list of the topics covered are shown in Table 2.

Users can go directly to specific systems, components, or locations through the top drop down menus. Each page is then cross-linked back to the related pages. All of the homework style problems can be accessed through the Assignments section. The material is not made to be used with a specific textbook so the problems are divided up into generic topics. Each skill-based problem includes links to a printable pdf and a link to related information on the Engaged site. The Plant Assignments problems involve more thought and are often open-ended. They are created from actual problems that have been researched at the facilities.

Examples of the Engaged pages are shown in Figure 1 and Figure 2. The current version of the material (Version 4) can be found at http://cset.mnsu.edu/engagethermo.

Table 2: Topics covered in Engaged in Thermodynamics (as of Jan. 2014).

Locations	Minnesota State University, Mankato Facilities Plant The College of New Jersey Cogeneration Plant Faribault Energy Park Monticello Nuclear Generating Plant
Systems	Steam Turbine Power Plant Gas Turbine Power Plant Combined Cycle Plant Cogeneration Generator Sets Centralized Heating and Cooling Plant Military Tanks (Drivetrains)
Components	Boiler Chiller Cooling Tower Steam Turbine Gas Turbine Diesel Engine Fuel Cell

III. Engagement vs. Motivation

As described, the intent of the Engaged in Thermodynamics material has been to increase student engagement. Integral to an assessment of this is the definition of engagement used. Other terms that have been used for engagement include "quality of effort" and "involvement".[8] Student and faculty opinions of what constitutes engagement have also been shown to differ.[9] A competing but related concept is motivation. Through a study of tools in use to measure engagement and feedback from student focus groups a set of brief questions were developed to measure engagement. These were rated on a 5-point Likert scale. The underlying belief was that students who were more engaged would devote more time to the topic. However, assessment results have indicated that this cause and effect relationship may be too simple [2]. Results indicated that while students might express more interest it did not automatically correlate to more activity related to the topic. Follow-up discussions with students suggested that time devoted to a topic may actually have little to do with engagement but more to do with other factors (such as grades in other courses).

This suggests several themes for further study and research. The first is not new but bears repeating for emphasis.

> *What is the definition of engagement? What is the definition of motivation? Do our assessment tools for these items really measure what we think?*

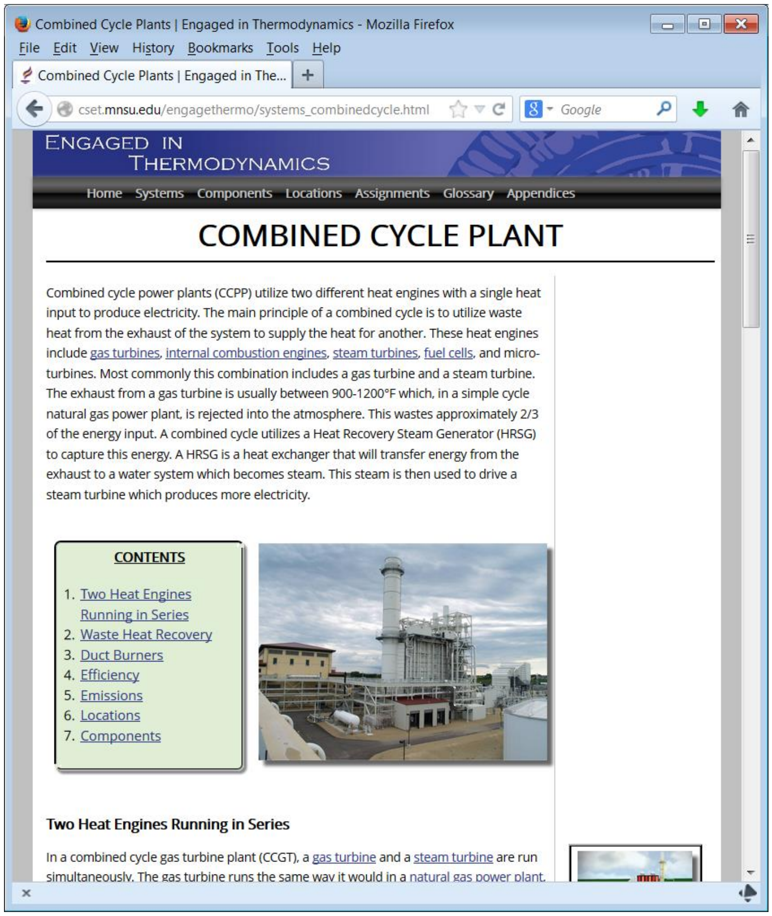

Figure 1: Example of a System page from the Engaged in Thermodynamics website.

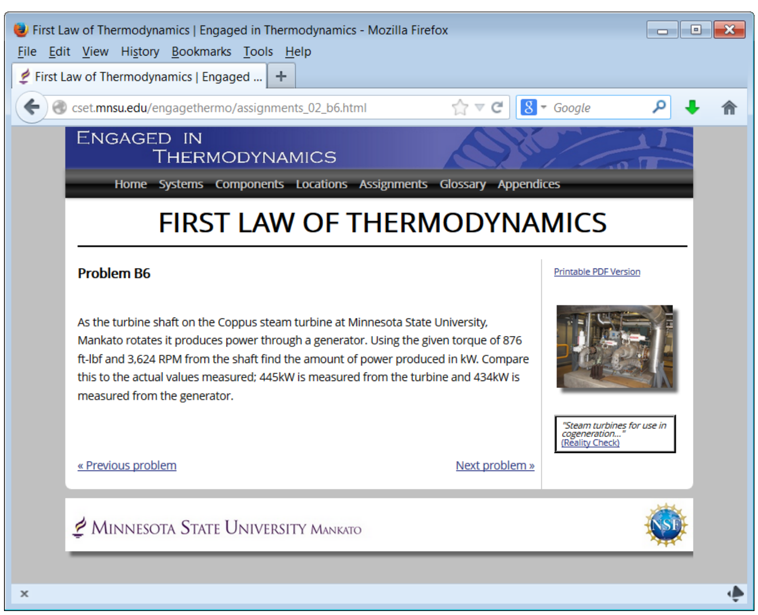

Figure 2: Example of a skill based problem from the Engaged in Thermodynamics website.

Assuming that there is a difference between engagement and motivation, students may be more *engaged* by the Engaged in Thermodynamics material but do not exert more effort or improvement because they are still not *motivated* to do so – or they are more motivated to do something else. This leads to a second theme for exploration.

> *Does engagement lead to motivation? Does motivation lead to engagement? Do you need both to improve understanding?*

IV. Student Use of Electronic Material

During the Phase I research a student focus group was asked to evaluate and explore several different thermodynamic textbooks on the market. These ranged from purely traditional paper books to completely electronic versions. At the time (circa 2006) students did not prefer the electronic material. They admitted they seldom used available online tools and would prefer a solidly bound paper text [7]. At the time students were not able to use computer based texts on exams. However, with the proliferation of smart phones and tablet computers this is no longer the case. Even the Fundamentals of Engineering examination has moved to a computer based testing environment with electronic reference materials. Due to these advancements this topic should be revisited, providing the third theme for further research.

> *Do students prefer paper or electronic textbooks? Does their preference depend on the course, due to topic or use?*

A related challenge throughout the Engaged in Thermodynamics research has been guidelines for the structural development and formatting of the material. There is a large amount of historical experience in writing paper textbooks. Likewise, there are guides and best practices for the design of web sites. However, the Engaged in Thermodynamics material is a mixture of both. The majority of formatting for the material was done by engineering students to ensure it was tailored as much as possible to their needs. Repeated focus groups were also used in the initial stages to determine how students were using the material. It quickly became evident that the material's impact can be adversely affected by things such as font size and positions on the screen. The fourth theme that needs to be investigated is:

> *How do students use online and e-textbooks? Is there a format that improves engagement? Is there an organization that simplifies use?*

V. Readability

During the first phase of development the student focus groups quickly determined that how the text was written affected student's interest. Sections of the material were then evaluated using recognized readability tests such as the Flesch-Kincaid grading level and Flesch Reading Ease tests. It was determined that the material was at an appropriate reading level. However, sections that were rated "Bad" by student reviewers actually had better reading ease scores. The number of passive sentences was also recorded and correlated much better than the readability tests. In other words, sections with more passive sentences were rated worse by students. This has opened up several questions regarding the material and existing textbooks.

> *How do existing textbooks rate with students for readability? How do existing textbooks rate on the readability tests?*

While the readability tests have been used widely it is unclear if they give the best impression of student desires. It also appears that the passive writing style affects student interest more than reading level. Research is already beginning to address the following questions.

> *Do the readability test scores correlate to student ratings? Do passive sentence counts indicate readability as well, or better, than the existing tests?*

VI. Conclusions

The Engaged in Thermodynamics material has been summarized in this paper. The material will continue to be refined and assessed in classrooms. However, it is evident that with greater pedagogical understanding and changes in industry applications this could be a never ending process. Research is cyclic and often generates new questions and avenues for further understanding. During the course of developing the Engaged in Thermodynamics material, several questions have arisen. Regardless of improvements to the Engaged material pursuing these research themes will provide useful information toward improved engineering pedagogies.

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Bibliography

1. P. Tebbe, J. Pribyl, and S. Ross, “Full Development of Engineering Scenarios to Promote Student Engagement in Thermodynamics – Year 1”, Proceedings of the 2010 Annual Conference & Exposition, American Society for Engineering Education, Louisville KY, 2010.
2. P. Tebbe, “Engaged in Thermodynamics – Student Engagement in the Classroom”, Paper ID #6566, Proceedings of the 2013 Annual Conference & Exposition, American Society for Engineering Education, Atlanta, 2013.
3. Felder, R.M., Woods, D.R., Stice, J.E., and Rugarcia, A., “The Future of Engineering Education II. Teaching Methods That Work,” *Chem. Engr. Education*, Vol. 34, No. 1, 2000.
4. Anderson, E.E., Sharma, M.P., and Taraban, R., “Application of Active Learning Techniques to Computer-Based Instruction of Introductory Thermodynamics,” Proceedings of the 2002 American Society for Engineering Education Annual Conference, 2002.
5. Light, R.J., *Making the Most of College*, Cambridge, Harvard University Press, 2001.
6. P. Tebbe, N. Saucedo, J. Pribyl, and S. Ross “Engaged in Thermodynamics: Addressing the Student to Learning Material Interface”, Paper ID #2011-1445, Proceedings of the 2011 Annual Conference & Exposition, American Society for Engineering Education, 2011.
7. P. Tebbe, S. Ross, B. Weninger, S. Kwamme, and J. Boardman “Assessing the Relationship Between Student Engagement and Performance in Thermodynamics Courses – Phase I”, Paper ID #2007-1722,

Proceedings of the 2007 Annual Conference & Exposition, American Society for Engineering Education, 2007.

8. Chen, H., Lattuca, L., and Hamilton, E., “Conceptualizing Engagement: Contributions of Faculty to Student Engagement in Engineering”, Journal of Engineering Education, July 2008.
9. Heller, R., Beil, C., Dam, K., and Haerum B., “Student and Faculty Perceptions of Engagement in Engineering”, Journal of Engineering Education, July 2010.