AC 2010-1114: FULL DEVELOPMENT OF ENGINEERING SCENARIOS TO PROMOTE STUDENT ENGAGEMENT IN THERMODYNAMICS – YEAR 1

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1. Background on Project Concept

Many thermodynamics courses are taught with traditional teaching methods and textbooks. Thermodynamics is prone to elicit a negative impression from students "who perceive the subject as dry and abstract [1]." While there has been progress in recent years with online activities, most textbooks offer limited visual aids and few descriptions 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. The result is that many students have excessive difficulty with the subject and do not develop a "feel" for the importance of the topic or the associated real-world equipment [2,3]. 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 [4]."

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 [5,6,7]. This engagement can be fostered by presenting material and problems in the context of concrete applications or requirements and by connecting problems to the student's pre-existing knowledge. As stated in Huet et al. [8] courses "should present real-world problems, in which future engineers are expected to not only understand the phenomena involved but also to solve problems".

Additionally, information on how a practicing engineer would attack problems is rarely presented for many textbook or instructor derived cases thereby limiting their impact. Research into good teaching practices, and active learning methods in particular, demonstrates that students' performance improves when strategies and skills are modeled for students [9]. In other words, students learn best when they see how others approach and solve a problem. With respect to critical thinking skills and design methods it is obvious that the best techniques to model are those actually used in the real world by practicing engineers.

While it is clear that all students' engagement could benefit from greater real-world content and design information there are also advantages in terms of retaining certain categories of learners, such as female engineering students. Studies indicate that students who are not retained in engineering "are more oriented toward creativity and innovative, 'out of the box' thinking processes, and who thrive in environments where divergent thinking, opinion generating, and subjective interpretations are encouraged" [10]. In addition, female students may not be suited to a "chalk-and-talk" style of education and "a broadening of curriculum and classroom teaching styles and strategies would help retain a greater proportion" [11].

The Phase 2 project builds on a successful and very informative Course, Curriculum, and Laboratory Improvement (CCLI) Phase 1 project that developed supplementary material for use in the engineering classroom, specifically for thermodynamics courses. In the original concept, an "Engineering Scenario" was created based on a specific real-world engineering facility in a form similar to, but expanded from, a case study. The scenario included extensive background information on the facility, including images and schematics of key components, narratives on facility history and purpose, and information on the engineering personnel responsible for the facility. The complete scenario is generated from a combination of narratives, 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.

In agreement with the work of Pascarella and Terenzini it was found that a simple instructional change can "increase a student's active engagement in learning…and enhance knowledge acquisition…." [12]. The Phase 2 expansion currently underway continues to address the student learning concerns of engagement and real world exposure by fully developing the Engineering Scenario concept, evaluating it at multiple institutions, and building a community of experienced users.

2. Phase I Progress and Results

To test the original scenario concept, material was generated around the engineering facilities of Minnesota State University Mankato (MSU), located in southern Minnesota. This supplementary material was designed for dissemination in an electronic format (http://cset.mnsu.edu/engagethermo) and for use with standard thermodynamic textbooks on the market. 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. Walk through videos of the plant were added to allow the students to get a better perspective of the size and location of all of the equipment. Audio commentary was provided on these videos by undergraduate research assistants working on the project. For all skill-based homework problems a "Reality Check" link was provided in the problem statement (see Figure 1). This link takes the student directly to the location in the Background information that described the related real-world aspects of the problem. This made the material easier to use and navigate and promoted more student investigation into the problem background.

Increasing use of videos was made as the project developed. To improve the student's ability to gain perspective on size and position of equipment several "walk-through" videos were produced. This were made to ensure that objects (such as students) were present to provide size comparisons. To reinforce the real world side of engineering video interviews were also conducted with a number of people involved with the plant (Figure 2).

In response to student comments that they were still missing the "big picture" other additions were made. Students 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

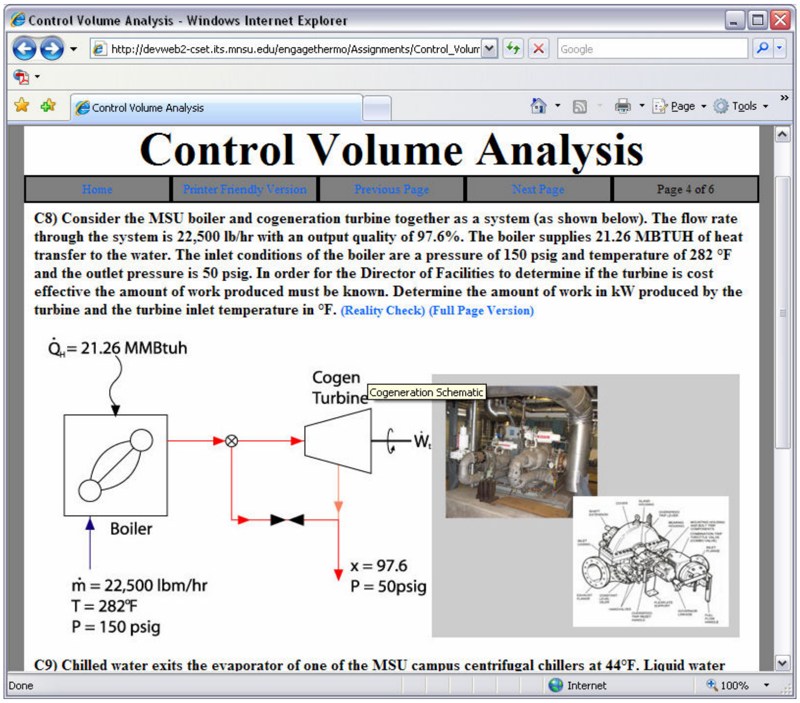

Figure 1: Example of a skill-based problem dealing with control volumes.

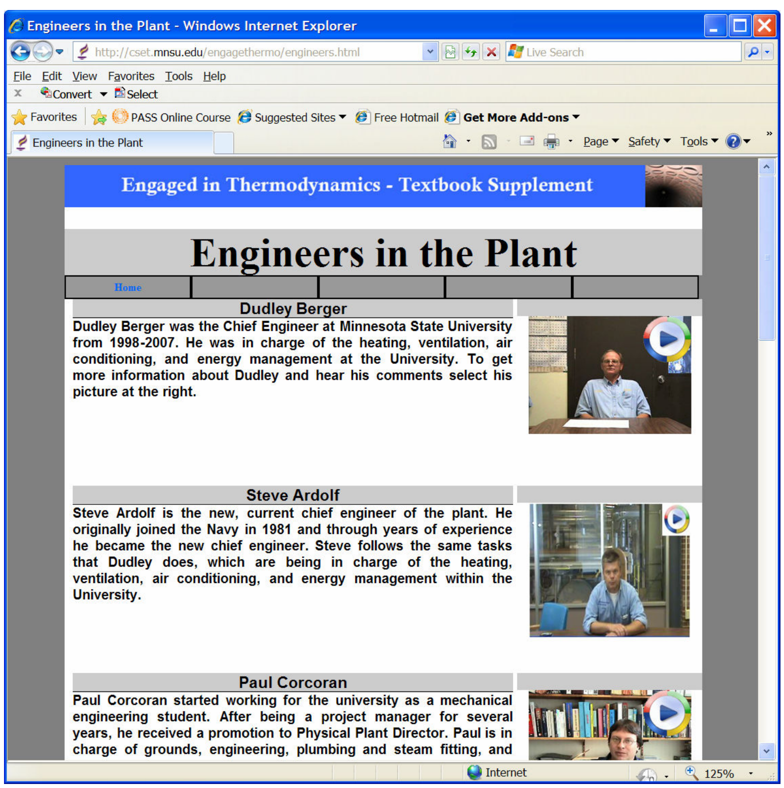

Figure 2: Examples of engineer interviews provided with the Engaged in Thermodynamics material.

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 that they found interesting or which engaged them in the courses, and their impression of the topic after the courses. For each major homework section, such as “Control Volume Analysis”, an introductory page was added before the problems. This page provided a brief definition of the topic, a link to glossary terms, hints for solving the problems in that section, and the newly developed student commentary.

Another addition which was largely spearheaded by the undergraduate research assistants was the addition of student modeled 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. The students provided commentary on how they were solving the problem and what their approach was.

Student assessment results demonstrated the value of the material concept and the features that were added. Overall, it was found that students have high expectations of being exposed to real world content in thermodynamics. With a traditional textbook these expectations were not met, however; using the Engaged in Thermodynamics supplement student expectation of real world content was satisfied. However, the most valuable assessment data was not quantitative but qualitative. An outside assessment coordinator met with students repeatedly in a focus group format to determine the impact of the new material. A sampling of their comments is shown in Table 1.

Table 1: Sampling of Student Comments from Focus Groups

“The textbook is boring overall. Does not encourage one to read it.”
“Traditional lecture is weak, does not lead to engagement at all.”
"Book problems rarely applied to real life situations."
“I think real world problems are important so I can relate them to myself and be more interested.”
"The (scenario) design projects, being open ended, led to self directed learning. Much must be done by students as investigation takes place and calculations are made.”
"The scenarios seemed much more like problems we might deal with in a job someday."
"The scenarios gave a sense of steps to take in the real world—had to investigate things. They helped review information learned so concepts were understood better. They helped students see the big picture by grouping ideas together."

3. Phase 2 Engineering Scenario Development

The original concept for the Engineering Scenarios was that each one would focus on a specific location. This was subsequently modified slightly for the Phase 2 work. The revised concept will create scenarios based on generic engineering facilities but with substantial reference and background on multiple physical sites of similar function and purpose. In addition, several mini-scenarios will be added addressing engineering applications that may not warrant a full scenario. These changes have been made due to assessment feedback from both students and faculty. Student's expressed a desire to go more in-depth on how things work and what other options exist. Faculty expressed a concern that the material should be made more diverse. It is believed that by including information on several sites under a common theme the "story" will be more interesting to a diverse group of students.

Several preliminary facility types have already been selected for the full and mini scenarios (Table 2). These have been selected based on 1) relevance to the thermodynamics material and industry, 2) access to a regional site for the MSU team, and 3) frequency of similar sites. In other words, they are sites that can be reasonably researched at MSU while being common enough that a student anywhere in the nation, or world, can relate to a similar facility nearby.

As can be seen, this selection of sites allows all major topics in thermodynamics (with the possible exception of compressible fluid flow) to be addressed as well as a number of interesting real world aspects. For instance, the Campus Facilities Plant will deal heavily with steam properties and the HVAC facility will focus on ideal gas and psychrometric properties, both for open systems analysis. While many of these scenarios include closed systems, the inclusion of the Internal Combustion mini scenario assures that closed systems can be adequately addressed. The addition of the Solar Thermal Power scenario also opens up the possibility for more coverage of solid and liquid property calculation in open and closed systems. Finally, by including the Ethanol Processing and Fuel Cell scenarios it will be possible to better address chemical thermodynamic issues (which is particularly important if the material is to be used for chemical engineering courses). All of the scenarios allow for the introduction of 2nd Law, entropy, and exergy components.

As previously mentioned, each Engineering Scenario will be 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 type of facility, including items such as images and schematics of key components from multiple sites, narratives on facility histories and purposes, and information on the engineering personnel responsible for the facilities. For each scenario a series of problems will be 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 type, 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. A greater sense of cohesion and continuity in the material will therefore be generated.

Following the proof-of-concept development plan, the skill-based problems will take the form of traditional homework problems and will emphasize the development of specific skills, such as

Table 2: Selection of Full and Mini Scenario Facilities

Full Scenarios (5 facility types) Campus Facilities Plant including Co-generation Power plant (Brayton-Rankine combined cycle plant) Nuclear power plant Ethanol processing plant HVAC facility **Mini Scenarios (4-6 application types)** Internal combustion engines Refrigeration/Chiller units Solar Thermal Power Fuel Cells

the use of specific equations or theories and basic calculation steps. These problems will differ from existing textbook problems in that they will be written in the context of an existing facility instead of being written in generic terms (Figure 1). These problems will also provide direct links to further information on the purpose, equipment, and data of the facility (i.e. the Reality Check links). This will open up the possibility of greater student directed learning. As the student works the problem they will be able to quickly locate further information and research specific points of interest concerning the problem. Based on the PIs' experience students often have questions about the real world implications of a homework problem or application. By basing these problems on a specific and well-researched facility the instructor's knowledge is fortified and the students' interest can be exploited to encourage greater engagement.

The use of both short and large design problems was shown to have great cognitive flexibility during the proof-of-concept. Short design problems are more open-ended than skill-based problems but still have a limited scope. They may involve specification and selection of key parameters or they may require identification of needed information. In other words, they require a cognitive level above normal homework but do not anticipate that the student have the full range of abilities needed for a completely open-ended problem. In terms of a measure such as Bloom's taxonomy, the use of the short design problem allows the instructor to pace student's movement up the taxonomy. As with the skill-based problems these will be written in the context of the scenario environment but will take into greater consideration the normal tasks required of an engineer there.

The large design problems will be similar to existing textbook design problems, however; they will be based completely on an existing design challenge from the scenario facility. All points of the description, data, and objectives will be taken from the real-world facility. Coupled with this will be an in-depth description of how the problem was approached and solved in reality. During the proof-of-concept the mere addition of typical industry units was very enlightening for the students. Of course any real world problem will involve many issues outside the scope of a thermodynamics course, for instance life cycle cost analysis and reliability. Where possible, elements of integrated design issues will be included in the problem, however; in the majority of cases it is expected these issues will be beyond the scope of the course (in terms of time and material coverage). These aspects will therefore be described or referenced in the linked information. This not only gives the student the potential to address topics which interest them, it offers the faculty member great flexibility in classroom discussion and coverage.

While design problems do not have a single inherent solution there are common professional practices used to address certain problems. Each large design problem will have available to the instructor solution hints, an industry modeled solution of the basic design problem, and the industry solution. These solutions will be developed based on input from, and in consultation with, engineers at the actual site. The full solution will be presented as a first person accounting from the on-site engineer (similar to a case history). This is intended to strengthen the exposure to real-world practices and to provide valuable information to the student. In order to assist instructors using the material, guidelines for student assessment and a grading rubric will be developed. These will be developed in conjunction with industry personnel in order to take into account what practices are successful in the real-world setting. They will also take into account recent pedagogical research in the assessment of student design activities [13]. During the proof-of-concept, development of the industry modeled solutions proved to be a difficult endeavor due to time constraints. Therefore, to facilitate this during the Phase 2 work several industry representatives have already been recruited to serve on an Advisory Committee.

4. Ongoing Development

The full development material will follow the same organization as the final proof-of-concept material. It will be structured as a textbook supplement suitable for use with any of the major textbooks on the market. It will be produced in an electronic form allowing for maximum use of cross linking material and easy dissemination (web or DVD based). Based on an initial student survey and focus group the material has been structured so that hard copies of all material can be easily obtained. Therefore, the majority of pages will have links to pre-formatted pdf versions of the material.

The two largest areas of fine tuning needed (as determined by Phase 1 assessment) are in problem wording and final formatting. Student feedback 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. Therefore, for the full development a new member has been added to the project team with science education knowledge and experience evaluating the readability of textbooks.

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