AC 2012-3990: USING VIDEO MEDIA TO ENHANCE CONCEPTUAL LEARNING IN AN UNDERGRADUATE THERMODYNAMICS COURSE

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Using Video Media to Enhance Conceptual Learning in an Undergraduate Thermodynamics Course

Abstract

This project addresses the need for changing undergraduate chemical engineering education to take advantage of skills possessed by a media savvy generation of students. A student's conceptual understanding is often decoupled from their problem solving ability. In other words, mathematical solutions are often attained in the absence of fully understanding the physical system and/or meaning of the result. Introductory thermodynamics is an undergraduate chemical engineering course wherein confusion in fundamental concepts may create a significant barrier in effectively solving problems. Some of these concepts are abstract, causing many students to not easily relate to them.

A collaborative team from Manhattan College, Bucknell University, and the University of Kentucky will enhance conceptual learning through a new and innovative approach. We will have students: 1) develop an instructional video that teaches a concept in thermodynamics using common metaphors, and 2) watch a similarly constructed instructional video developed by peers at a separate institution. The former employs autodidactic learning, while the latter takes advantage of peer-to-peer learning. To measure the effects of these treatments on conceptual learning, our project will execute: 1) a baseline assessment using a thermodynamics concept inventory, and 2) a post-treatment assessment using a similar instrument. Additionally, student affective domain responses will be measured with a questionnaire using standard Likert ratings.

This project has broad implications for increasing conceptual understanding in thermodynamics for both undergraduate engineering students and the general public. Thermodynamics is a core course in other engineering disciplines (e.g., mechanical engineering). Thus, the videos generated from this project are designed to impact a wide range of engineering students. Moreover, the use of publically accessible cloud-based service to host the videos will guarantee broad and rapid availability to institutions of higher education and the general public. As the collection of videos grows, students from diverse backgrounds and capabilities will find one that addresses their individual needs and learning style. Finally, faculty embracing this project will have an opportunity to have their students view the videos to supplement lectures, as well as contribute to the collection. With respect to the general public, non-engineers curious about thermodynamic principles will have an opportunity to gain insight on a particular concept, because the instructional videos will use ordinary examples.

Introduction

This work seeks to address a recognized need to improve conceptual understanding in engineering education (Bransford et al., 2000). Students who can accurately solve equations and textbook problems may still give incorrect answers on conceptual questions that do not involve calculated solutions (Halakova and Proska, 2007). For example, in a draft concept inventory examining ñentropyò understanding in thermodynamics students, the mean post-instruction score was only 44%. This result was not correlated with student grade point average, suggesting that even when students could perform well on other thermodynamics tasks, their conceptual understanding did not reach mastery (Prince et al., 2010a). A typical concept question for entropy might be:

> ñConsider the best possible heat engine working in air at 25ºC. The engine continuously converts heat from a source at 300ºC to work, and heat is continuously transferred to the engine at a rate of 100kJ/second. What is the maximum possible rate at which the engine could possibly produce work? A) 100kJ/s B) Nearly 100kJ/s C) Significantly less than 100kJ/sò.

A less conceptually based version of the same question might read:

> ñCompute the thermal efficiency of a Carnot engine working continuously with a heat source at 300ºC and a heat sink at 25ºC.ò

While it is crucial that students develop an accurate understanding of engineering concepts, it is also true that typical lecture-based classroom instruction has been shown to have a limited impact on conceptual understanding in technical areas. For example, in a large meta-study of physics students using the Force Concept Inventory, only a 23% improvement was found between pre- and post- test scores for ñtraditionalò courses. In the area of Engineering Heat Transfer, a multi-institution concept inventory study showed a mean pre-test score of 49.2% and a post-course improvement to only 54.5% after traditional instruction (Prince et al., 2010b). Finally, using the same Thermodynamics concept inventory proposed for assessment of this work, an improvement from a mean score of 48.9% to 60.0% was found between pre- and post- course scores at six institutions (n=199). Each of these results involves students from multiple institutions, large and small, public and private, across the United States. While the post-instruction scores are indeed significantly higher than the pre-instruction scores, none of the post-test scores rises to the level expected for students achieving mastery in these areas.

Fortunately, a variety of methods that cause students to confront their misconceptions in more substantial ways than lecture have been shown to achieve greater improvements in conceptual understanding (Treagust and Duit, 2008). For example, the use of **inquiry-based activities** leads to significant improvement in conceptual understanding for both physics students and engineers (Laws et al., 1999; Prince et al., 2009). In the inquiry-based model, students predict the outcome of an experiment, conduct the experiment, and then revisit their predictions and critically compare them to actual results. This approach has demonstrated success in both physics and engineering education. Another approach demonstrated in chemistry is **Scientific**

Concept Construction and Reconstruction, where the emphasis is on encouraging students to apply logical scientific reasoning to repair alternate conceptions about science (She and Liao, 2010). Pugh et al report that students having a deep level of engagement and transformative experience with the subject matter are more likely to engage in conceptual change (Pugh et al., 2010). More traditional **active learning** has also been shown to have a positive effect on conceptual learning in physics (Baser, 2006). Finally, in the process of **reflective writing and reading,** the reflective writing of peers can be an effective method for producing conceptual change in college students (Zhang, 1999).

There are several elements common to these approaches to conceptual change. Initially, students make a prediction about a given situation. Then, either through direct experience, simulation, reading, or discussion, they engage with the outcome from that situation. Then, through reflective writing, peer or faculty discussion, or adaptive computer interface, they revisit their original prediction and reassess their thinking in light of the new experience. Key to the effectiveness of these processes are that: a) students must experience conflict, in which they see their previous conception fail, b) they must deeply reflect on this conflict, and, finally, c) they must be motivated to resolve this conflict. We seek to incorporate these elements into a novel method for teaching engineering thermodynamics concepts through student production of concept-related videos.

Instruction through use of student-generated video media is not yet prevalent in engineering education, but some examples exist (Taylor, 2010). Video assignments have been more common in pre-college education as well as in higher education outside of engineering (Schuck and Kearney, 2004; Kearney and Schuck, 2006). In most contexts, these videos replace written reports, and when properly designed, improve upon the educational experience relative to written work. Students are highly motivated by the idea of video production relative to writing (Howe, 2009). Video has the potential to aid engineering students in conceptual change, in particular, because:

a) Engineering students are overwhelmingly ñvisualò learners (Felder and Brent, 2005)
b) Incoming college students are typically technologically savvy and have a high expectation for use of Web 2.0 technologies (Duffy, 2008)
c) Many thermodynamics concepts are abstract, but amenable to explanation through visual metaphor.

Student-produced video has been shown to be an effective approach to facilitate student learning in several non-engineering fields (Powlik and Fortenberry, 2001; Herder et al., 2002; Schuck and Kearney, 2004; Kearney and Schuck, 2006; Schuck and Kearney, 2008; Bo-Kristensen et al., 2009; Herrington, 2009). Further, sharing and watching the videos produced by peers has shown promise outside of engineering (Bo-Kristensen et al., 2009; Herrington, 2009). We anticipate that the application of this approach within thermodynamics will result in significant improvement in student conceptual understanding of this area.

Methods

While some of the minimal requirements for implementing the video component of these assignments are readily available (for example, both MacOS® and Microsoft Windows® now include basic video editing tools), this project will enable students to pursue their creative ideas. Each participating institution will be equipped with HD capable video cameras, A/D video capture devices, suitable audio capture equipment, and both professional and consumer-oriented video editing and animation software.

A single dedicated video editing machine with professional capture and editing hardware (e.g., Matrox RT X2) and software (e.g., Adobe CS5) will be available at each institution, along with additional licenses for key software packages (e.g., screen capture with Techsmith SnagIt and Camtasia, basic animation) for use on existing laboratory computers. To address the need of facilitating video production, custom training sessions for using this software will also be provided by one of the investigators (primarily from existing Web sources, but also custom-generated tutorials for students as needed).

Commercial video hosting sites will be used to stream the resulting videos (YouTube EDU or another suitable host), with embedding enabled to allow course Web pages or CMS to integrate those videos. Beyond this project, the videos will be disseminated as part of a larger Web site in development by the Education Division of AIChE to make such educational resources readily accessible by all chemical engineering instructors. Because many will be of broader interest, topics will also be indexed with The National Science Digital Library (NSDL.org) and the Merlot.org website.

Assessment of the studentsô conceptual understanding will be documented primarily through use of the Thermodynamics Concept Inventory developed by Vigeant et al (Prince et al., 2009; Vigeant et al., 2009; Vigeant et al., 2010). This assessment was developed as part of prior NSF support (DUE# 0717536). Testing with undergraduate engineers across the country has established that this assessment is a reliable measure of conceptual understanding in thermodynamics using Kuder-Richardson Formula 20 (KR20 = 0.80). The concept inventory consists of 36 multiple-choice questions and exists in an online format for ease of administration and data collection.

Preliminary Work

Abulencia assigned thirty two sophomores in a spring semester 2010 introductory fluid dynamics course to generate a video that describes a concept of their choosing (e.g., YouTube™ website, SEARCH TERM ñSeries and Parallel Pump Operationò). A candidate list of topics was provided in the assignment description, though they were not bound to using any of those. Students were not given any equipment or editing software to accomplish this task during the five week timeframe of the assignment. At the conclusion of this work period, the class collectively viewed all of the video contributions, and was asked to fill out a survey using a 5 level Likert rating where 1 = Strongly Disagree, and 5 = Strongly Agree. Table 1 displays the results.

Table 1 ï Post-project student survey. A rating of 1 = Strongly Disagree, while a rating of 5 = Strongly Agree . (n = 23 respondents)

	Question	Mean (SD)
1	Making a video in this assignment was useful in learning principles in fluid flow	3.78 (0.59)
2	There was a large learning curve in producing this video	3.78 (1.12)
3	Participating in this project was enjoyable	4.22 (0.73)
4	I feel that students who have not taken this class will learn from the video my group produced	4.13 (0.91)
5	This assignment can be extended to other courses (e.g., thermodynamics, and material and energy balances)	4.13 (0.75)

In addition to answering these questions, students had three free response prompts. The first asked, ñWhat are the strengths of this assignment?ò Many students wrote that the assignment was ñfunò or ñenjoyableò (which corresponds to the response with respect to survey question #3), that ñyou had to really learn the topicò as well as ñforces students to understand conceptsò. The second free response question asked, ñWhat are the weaknesses of this assignment?ò A large portion of the responses said that it was hard to accomplish (i.e., editing) without the appropriate equipment. This attention devoted to producing the video may have contributed to the tepid results for question #1. More specifically, the students appear to have spent a lot of time in working out the details to produce the video, rather than focusing on learning the concept. Despite this result, the students felt that their video was useful in teaching others (i.e., question #4) and that it can be reproduced in other courses (i.e. question #5). The last free response question asked, ñWhat changes/improvements would you make to this assignment?ò The overwhelming majority replied that a topic should be assigned rather than allowing them to choose. After directly speaking with the students, the reason behind this response is that they selected topics they were most comfortable in, thus resulting in a smaller degree of learning compared to performing the assignment on a concept that they do not initially grasp.

From this preliminary work, two logistical adjustments emerged from the student responses:

1) Video production must be facilitated by providing equipment that is intuitive and easy to use.

2) Topics should be assigned rather than allowing students to choose.

These elements were incorporated into the experimental design of this work.

Conclusions

In conclusion, this work will demonstrate the effectiveness of using video to enhance conceptual learning in an introductory thermodynamics course. Students will develop and/or watch an instructional video that teaches a concept in thermodynamics using common metaphors. The effects of these treatments will be measured using a thermodynamics concept inventory. The major outcomes of this work are that students will have an improved conceptual understanding of thermodynamics principles as a result of developing and/or viewing the aforementioned instructional videos. The results are important in advancing knowledge in chemical engineering education because a positive outcome will demonstrate that watching and making videos promotes improvements in the affective domain, as well as improved conceptual learning from both peer and self instruction. Additionally, the project is intended to inform not only those in the chemical engineering community, but is intended to play a role in the education and retention of women and other traditionally underrepresented groups in engineering, plus members of the public sector interested in thermodynamic principles.

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