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Teaching Thermodynamics Through Video Media

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TEACHING THERMODYNAMICS THROUGH VIDEO MEDIA

Abstract

This paper discusses the teaching of concepts in an introductory thermodynamics course through video. This generation of students is technology savvy, and regularly communicates by means other than face-to-face interactions (e.g. texting). Additionally, the popularity of sites such as Khan Academy makes the idea of teaching with video difficult to ignore. Thus, we assert that there is value in using this media for instruction, and that this media can be leveraged for use in a chemical engineering course. During this study, students will be asked to 1) take a concept discussed during class, and articulate it in video media using everyday examples that other students can relate to (autodidactic learning) 2) watch peer-made videos that teach these concepts (peer-to-peer learning), and 3) a combination of both. Student learning will be evaluated using an established thermodynamics concept inventory. Ultimately, the authors envision a repository of videos where students from other institutions can contribute, and content be shared for use by other instructors.

Introduction

Successful teaching involves effectively communicating knowledge from an instructor to a student. This has traditionally occurred using a lecture format, where a person skilled in a particular subject disseminates information to a large number of students. Passive learning techniques such as these have given way to active learning strategies such as think-pair-share and problem-based learning (Prince and Felder ï 2006). Although there is still much value for these in-class strategies, chemical engineering education has yet to take advantage of the skills possessed by a media savvy generation of students. More specifically, millennials have been brought up in a world of SMS messaging, Facebook pages, podcasts, and video blogs, which have trained them to communicate and manage information from multiple sources and formats (i.e. text, video) both quickly and effectively (Schuck ï 2008). How can chemical engineering education best leverage these skills?

Electronic or ñonlineò learning is one of the first instances of using digital media for education. In this setting, learning occurs through reading course notes posted by the professor, or watching a lecture that is either live or pre-recorded. These two methods are inherently passive and do not effectively engage students, though their effectiveness in student learning has been debated (Chen ï 2009).

Websites such as YouTube and Khan Academy are popular resources that students use to learn. These videos can be created to be enjoyable so that students do not feel that they are studying or doing work. More importantly, students can repeatedly watch the video (or portions of it) until they completely understand the material. Educators can suggest these sites to supplement in-class learning, by having students watch and even create content as a part of their course requirements (Burke and Snyder ï 2008). Doing so can help inspire and engage this new age of students who are more used to digital tools and devices. Even the more traditional learner can use the sites as an opportunity to gain understanding in new technology, which can become skills for future careers.

Other work have utilized video technology with Chemical Engineering students. Liberatore has utilized YouTube to relate course topics to real world applications (Liberatore ï 2010). Falconer and colleagues have compiled screencasts where a narrator goes over a particular chemical engineering concept, or a detailed problem solution (Falconer 2009 and 2012). A recent paper from *JEE* states that students who use screencasts and perceive their benefit have better results on exams (Green ï 2012).

Although the studies cited illustrate student engagement and user comfort with the selected media, the study we are performing is different. We aim to apply video as a tool in an Introductory Thermodynamics course to elicit two different styles of learning: 1) learning that occurs in students developing videos that teach a concept (autodidactic learning), and 2) learning that occurs from viewing videos produced by peers (peer-to-peer instruction). Because most internet learning follows these two modes (i.e. think about the last time you had to look up something in the internet to get instructions on how to do something), it follows that this generation of student, who have much experience and reliance on the internet, will fit the schema we propose.

Methodology

The current work is a sub-set of a larger project designed to test the impact of both creating and viewing videos on students understanding of several important concepts within thermodynamics. The sophomore level Introductory Thermodynamics course is offered once a year at the authorsô institutions. This course is usually a studentôs first exposure to thermodynamics, and focuses on teaching vocabulary and concepts, and fundamental first-law problems.

The overall study has four treatment groups and will occur over a period of three years. Each of the three thermodynamics classes will be asked to perform a different task as described below.

Year 0 ï Baseline Control

The institutions participating in this study have previously submitted data for the Thermodynamics Concept Inventory (Vigeant ï 2011b). Briefly, students were asked to take the Concept Inventory during the first week of the semester, and the last week of the semester. Thus, this treatment group represents students who were enrolled in Introductory Thermodynamics, and did not perform any additional project while taking the course.

Year 1 ï Video Generation

Students will be asked to *generate* a 3-5 minute video that teaches a thermodynamics concept using common metaphors. They will be arranged into groups of three to five, and assigned a topic from a prescribed list. Students will be asked to take the Thermodynamics Concept Inventory during the first and last week of the semester.

Year 2 ï Video Viewing

Students will be asked to *watch* 3-5 minute videos that span the five topics covered in the Thermodynamics Concept Inventory. These videos will be selected from those generated in Year 1 of the study, and will be available after the videoôs topic has been presented in class. After watching the video, students will be asked to perform a short reflection assignment on the concept. Additionally, students will be asked to take the Thermodynamics Concept Inventory during the first and last week of the semester

Year 3 ï Video Generation and Viewing

Students will be asked to *watch* AND *generate* a 3-5 minute video that teaches a thermodynamics concept using common metaphors. Again, the required videos for viewing will be selected from those generated in Year 1 of the study, and span the five topics covered in the Thermodynamics Concept Inventory. Students will be asked to perform a short reflection assignment after each of the concepts, and will be asked to take the Thermodynamics Concept Inventory during the first and last week of the semester.

As mentioned, the Thermodynamics Concept Inventory is the instrument used to assess conceptual learning. Developed by Vigeant and colleagues, this assessment consists of 36 multiple-choice questions administered using an online interface that span over five topics that frequently cause misconceptions in students taking the Introductory Themodynamics course (Prince ï 2009, Vigeant 2009, Vigeant 2010). These topics are: 1) Entropy and the Second Law, 2) Reversibilty, 3) Steady State vs Equilibrium, 4) Internal Energy vs Enthalpy, and 5) Reaction Rate vs Reaction Equilibrium. The Concept Inventory is established to be a reliable measure of conceptual understanding in thermodynamics using the Kuder-Richardson Formula 20 (KR20 = 0.80).

The present paper is focused on year 1 activities, in which students produced videos addressing concepts 1-5 above. Students in each of the three participating thermodynamics courses were assigned a concept and given a framework for developing their video (see sample assignment in Appendix A). Instructors also provided or helped students access relevant equipment including video cameras and computers with editing software. The exact technologies available varied by institution, but were of comparable quality.

Results

Students, in teams of 3-4, produced a total of 21 videos. Students engaged in a variety of approaches, from more-lecture and equation based description to extensive use of analogy and metaphor. All teams were able to successfully create at least minimal video content, indicating that this medium of communication is poised to become part of the regular repertoire of student report as with PowerPoint and memos.

All three instructors viewed all videos and assessed them for both their accuracy in conveying the target thermodynamic concept and their videographic quality (cinematography, script, sound quality, etc.) on a three-point scale. Instructors then collectively viewed and discussed all videos on which their ratings did not agree. Videos passing the standard of both quality and accuracy in the collective judgment of all instructors were added to the video library for use in years 2 and 3. By this standard, at least one video in each concept area was acceptable, more in several cases.

Discussion

The primary objective of this study is to examine if video (generating and/or watching) increases student conceptual learning in thermodynamics. However, another outcome we wish to develop is the creation a repository of videos for students at other institutions to view and contribute. Thermodynamics is found in the curriculum of other engineering disciplines (e.g. mechanical engineering) and general engineering degrees at community colleges. Additionally, topics in thermodynamics may be seen as subtopics in courses such as general chemistry (e.g. calorimetry) and general physics (e.g. entropy). If students with different backgrounds contribute to the collection, it is likely that another student will be able to find a video that caters to their particular experiences and learning style (e.g. a student who does not live in an urban setting may not understand a metaphor centered around commuters exiting the subway during rush hour). Thus, the goal is to provide sufficiently different perspectives on a topic to cater most viewers.

New technologies and techniques are continually being developed to allow us to empower learners and enable learning. Current trends in education such as the ñflipped classroomò and the delivery of free courses through sites such as Coursera, EdX, or Udacity require students to interact with digital media. Despite their popularity, perhaps the results of our study can offer perspective on whether this mode is *effective* in helping them learn, or maybe weôve been doing it right all along.

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Appendix A: Sample Assignment

CHEG 310
Engineering
Thermodynamics

Project: Thermo for the People

Your Time to Shine

The machines that power our lives and make travel, cooking, and just about everything else possible are intrinsically thermodynamic objects. There is a lot of talk right now about making things "greener" or "more sustainable", but we can't really do that unless we understand, fundamentally, how these things work and what the limits on their efficiency are. It's important that we, as engineers, understand these systems, and it would be useful if everyone else did, too. In this project, you and your team will gain a deeper understanding of a thermodynamic concept and demonstrate mastery of the topic by explaining / demonstrating a complicated thermodynamic concept to a broader audience.

Project Description:

For one of the following concepts:

- Entropy
- The second Law of Thermodynamics
- Thermal efficiency of systems
- Reversiblity
- Internal energy
- Enthalpy
- Equilibrium
- Steady state
- The distinction between reaction equilibrium and reaction rate

Your team should produce the following:

Final product: A polished 3-5 minute video designed to be **interesting** and informative for a first-year engineering student (i.e. a smart person with high school science, but no technical engineering coursework yet). Note that the emphasis is on the *concept* – what is this idea, in plain everyday language, *not* on the mathematical application of the concept. Examples of appropriate video components include: performing an experiment, drawing and explaining a diagram or image, acting out a representation of the concept, some combination of the preceding. Singing, dancing, animation, or other creative forms of communication are welcome as long as the central concept is conveyed with accuracy. If this is sufficiently accurate and appropriate, it will be posted to YouTube and shared with other engineering students nationwide. *All videos will be shown in class.* ***NOTE: Our goal is for this work to be shared broadly. If you object to your name being shared outside of Bucknell University, do not list or use your name in the video. If you do not consent to appear in front of an audience, do not***

participate in the on-screen portion of this assignment. If no one on your team is willing to appear, use animation, screen-cast, or another format for your video.

Intermediate Products:

An initial personal reflection of approximately one page, explaining your understanding of this concept, at least one application of this concept in "real life", and a reason why non-engineers should understand this idea.

A ~1page summary explaining how your team will explain your concept, and then, briefly, explaining how you will incorporate that into a video, with a story-board / script as an appendix . Storyboard shows the breakdown of how your conceptual explanation will be enacted on screen (or script does the same in words).

A rough-cut of your video and written feedback on one other teams' rough-cut (form to be provided).

A final written reflection on your product: did your understanding of the concept change? How well do you feel it conveys the central concept.

Project Documentation Format:

Final: Export the video to a common electronic format (.mp4, .mpg, or .avi, for example) and submit to Dr. Vigeant either on CD / DVD or memory-stick. Hand in a cover sheet indicating: a) an outline of the answers to the four points addressed in the video b) an introduction aimed at me explaining why this is important. Plan to share your work in class by showing the video to your classmates.

Timeline:

- Wed, 3/28: Initial personal reflection due.
- Wed, 4/4: One page summary plus storyboard/script.
- Wed, 4/18: Rough-cut (un/semi-edited video footage) due for feedback; feedback on other teams' rough-cut due on Friday, 4/20 (email directly, cc-ing Vigeant)
- Thurs, 4/26: Final project due, by email / drop box/ memory-stick, written part by email. Video viewing 5/1.

Teams:

There will be 9 teams (four teams of four and five teams of three); these will be semi-randomly assigned based upon lab section and preferred seating arrangement. The four-person teams will be assigned the more challenging topics.

Grading:

Documentation (40pts): Technical correctness, accuracy, clear, grammatical and concise presentation of written work.

Video (60 pts): Technical correctness, accuracy, ascetics, creativity, audience-appropriateness, writing, and *wow factor* (is this something that will be fun / memorable / impressive for the audience while also being educational?)

Teamwork: Team-members will be asked to provide evaluations of the effort expended by themselves and their team-mates. These confidential evaluations will be used to adjust the project grade and create individual grades.

Video Production Tools:

+ This class will have four “new” iPads with iMovie, a cartoon creator, and a stop-motion app included. These can be used for filming and editing and may be borrowed on a 24-hour basis (a sign-up will be provided).

+ A USB microphone, for use with iPads or any other device with USB input, may be borrowed on a 24-hour basis.

+ The Equipment Desk in the library has a variety of cameras and microphones available.

+ The video lab (downstairs, library) has several high-powered video editing applications and storage

+ You are of course welcome to use any camera you have available as long as it produces output of sufficient quality. You need to verify that you can export footage to an appropriate device for editing (computer or iPad).