Cut! Adventures in Student-produced Instructional Videos for Thermodynamics

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Abstract

In this paper we will share the quantitative and qualitative results from our study of the impact of student-made videos on conceptual understanding in thermodynamics. We will also discuss the mechanics of assigning video production in a technical ChemE course. In its final iteration, students were tasked with watching and reviewing select videos from all three schools and all previous years as homework throughout the semester. In addition, students working in pairs generated two short videos providing metaphors to aid in understanding of two different thermodynamic concepts. Results include a large library of thermodynamics videos, suitable to act as “learning objects” for topic introduction or further study outside of class, enhanced student engagement, student demonstration of the capacity to engage in lifelong learning. By the draft paper due date, we will also be able to say whether or not it also resulted in a significant change in students’ thermodynamics concept inventory scores. In previous years of the study, simply watching videos or generating a single video on a larger team did not improve student scores over control.

Background

Peer instruction has been shown to be a powerful tool for learning\textsuperscript{(1)}. The goal of this work was to see if the benefits of peer instruction could be attained asynchronously via the medium of video. In the past decade, video has shifted from a medium requiring special training and equipment to one which most students have access to through their personal phone. Further, the popularity of YouTube and other image and video sharing sites with people 18-25 years old suggests that this is a medium that most of our students are comfortable with. In this study, students at three different institutions would make brief videos in which they demonstrated a metaphor to explain one of five challenging concepts in thermodynamics, and also watch videos made by their peers at each institution. We hypothesized that this might capture the educational benefits of peer instruction and the motivational benefits of using a “new” technology.

Table 1 shows the thermodynamics concepts used as a basis for the videos. These topics were selected because they are both important and difficult\textsuperscript{(2)} and also they are the ones assessed by the Concept Inventory for Engineering Thermodynamics (CIET), which was used to assess student learning. Students in courses with a typical lecture format tend to improve about 10 percentage points on this assessment over the course of the semester, while students with one or more enriching activities, such as inquiry-based activities, do significantly better\textsuperscript{(3)}. 

Table 1: Thermodynamics concepts addressed by student videos

<table>
<thead>
<tr>
<th>Concept</th>
<th>Misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entropy &amp; The second Law of Thermodynamics</td>
<td>Any device can be made 100% efficient if friction is removed.</td>
</tr>
<tr>
<td>Reversibility</td>
<td>Reversible functioning is both practical and attainable for most systems.</td>
</tr>
<tr>
<td>Internal Energy vs. Enthalpy (U vs. H)</td>
<td>These two state functions describe the same thing.</td>
</tr>
<tr>
<td>Equilibrium vs. Steady State (Eq. vs. SS)</td>
<td>These two terms are synonyms.</td>
</tr>
<tr>
<td>Reaction rate vs. extent of reaction</td>
<td>Any reaction that proceeds to completion must be rapid / the factors which contribute to extent of reaction are the same as the ones that control reaction kinetics.</td>
</tr>
</tbody>
</table>

Methods

Students in Chemical Engineering Thermodynamics courses at three institutions participated in this study. Since this course occurs during different semesters in the participant institutions, treatments will be designated by year from the project’s inception. In Year 0 or the “control” year, videos on these difficult thermodynamics concepts were neither made nor watched. In Year 1, student teams of 3-4 made a ~5 minute video on one challenging concept from Table 1. In Year 2, students watched the videos made by the previous year’s (i.e. Year-1) groups as part of their homework and did not make videos on these concepts. These videos were made available through each institution’s course management system. The assignment for watching videos is shown in Appendix B and was assigned as part of normal homework. Students were only shown past videos judged by the three faculty to be conceptually correct and of high quality. In Year 3, students both made and watched videos – videos from years 2 and 3. In Year 4, students again both made and watched videos, however student teams were shrunk to two students and each team was asked to make two two-minute videos on difficult concepts.

Quantitative change in students’ conceptual understanding was assessed using the concept inventory for engineering thermodynamics (CEIT$^{4}$), which was given to students at both the beginning and at the end of the semester, at time period of approximately 14 weeks. The CEIT consists of 35 conceptual about the five topics in Table 1. Towards the end of the semester of this past year of the study (Year 4), student pairs were assigned to make two brief videos about difficult concepts in thermodynamics. The assignment was substantially the same at each institution, and is attached as appendix A. Qualitative results are based upon instructor evaluation of the videos themselves and student comments in the post-video reflection.

Each institution had a different approach to enable student video production. Early in this study, institution [A] provided student groups with high definition (HD) cameras and laptops installed with video editing software. As the study progressed and personal mobile devices such as
iPhones and iPads acquired the ability to film in HD, students were given the choice to use the aforementioned equipment or their own, with the stipulation that the final product be in high definition. At [B], the faculty member made a number of iPads available to the students, along with tripods and microphones. Students who used the iPads were able to edit video directly on the device using iMovie. A number of other apps, including TouchCast, Explain Everything, and Stop Motion Studio were also made available but used less frequently than iMovie. At [C], students were given access to semiprofessional cameras and editing software on dedicated machines with either iMovie or Adobe Premiere installed, though most students used their personal devices and editing software which came with their device or was provided by University site license.

**Results and Discussion**

Table 2 shows concept inventory results for students in control and years 1-4 of the project. On a positive note, students consistently improve significantly from pre-test to post-test, with a large effect size (d=1.33). We can confidently say that the thermodynamics course had a positive impact on students’ conceptual understanding in thermodynamics. On the other hand, in Years 1-3 there is no significant change in performance relative to Year 0, the control year, when no videos were either made or watched.

**Table 2:** Aggregate Results of Concept Inventory from All Three Institutions; all post-tests are significantly better than pre-tests, no significant difference between post-test and control for Years 1-3; significant decline in Year 4, p<0.01.

<table>
<thead>
<tr>
<th>Year 0 - No video project (&quot;control&quot;)</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1 - Made video only n=76</td>
<td>47.1%</td>
<td>64.3%</td>
</tr>
<tr>
<td>Year 2 - Watched video only n=68</td>
<td>44.6%</td>
<td>65.7%</td>
</tr>
<tr>
<td>Year 3 - Made and watched videos, large teams n=81</td>
<td>44.6%</td>
<td>65.7%</td>
</tr>
<tr>
<td>Year 4 - Made and watched videos, short n=75</td>
<td>44.6%</td>
<td>60.9%</td>
</tr>
</tbody>
</table>

The original plans for this project extended for three years. However, our concept inventory data at the conclusion of that time period indicated that students did not improve relative to the control for making videos, watching videos, or for making and watching videos (Years 1-3). In contrast, feedback from students in project reflections and post-course conversations indicated that many students believed they had learned about thermodynamics from the project. Consequently, we determined that an additional year of testing with a revised assignment was warranted.
Revisions were driven by several observations of student behavior. Specifically, the teams of four students employed during the original design (i.e. Years 1-3) allowed them to specialize, and we often observed one or two team members being responsible for the video filming and editing, while the others specialized in the thermodynamics. Further, each team only considered one of the five important concepts that were the focus of the study. Conversations with students indicated students felt they had learned their concept well, but typically did not mention the other concepts. And finally, five minutes is a long video by today’s standards, and there was a tendency for some teams to use the extra time for entertaining irrelevancies. The revised assignment applied in Year 4 addressed these issues by shrinking the teams, asking each team to create two videos on different topics, and limiting video length to two minutes. As can be seen in Table 2, the changes made for year four did not have the intended effect. In fact, the post-test score dropped significantly from the “control” post-test, the only year to do so.

We conclude that creating and/or watching conceptual videos are not an effective technique for boosting conceptual understanding. While students often report in their reflection that they feel they understand their topics better – for example “Looking back at my reflection before I started the videos, I noticed my understanding grew a little for each topic” from a student at institution [B] in Year 4 - this impression is not realized in the concept inventory. It may be that the additional cognitive load from practicing a new or unfamiliar skill cancels the benefit from thinking more deeply about a particular concept. Or it may be that students work focuses on the concepts that they already feel they understand, and so working on the videos reaffirms existing understanding rather than causing reevaluation of misconceptions.

Qualitative results from this work are more promising. Student reflections on the project indicate that the students felt they had learned their targeted concepts better, and also that many of them learned basic video filming and editing. Faculty observations suggest that students associated learning more strongly with making videos than with watching them.

At institutions (A) and (B) no instruction in filming or editing videos was provided, rather the students were pointed towards on campus and internet resources to answer their questions. This was done deliberately as an exercise in which successful students would demonstrate the capacity to engage in lifelong learning. Scores on video quality were used as a proxy to demonstrate this outcome for departmental ABET assessment at institution [B]. All students were successful in demonstrating the capacity to self-teach. Institution [C] took a similar approach, with some direction to tutorials on various software packages provided and assistance on specific tasks given, but students were primarily self-taught.

The authors reviewed the students’ videos and determined that over 30 of them are of high enough educational quality for ongoing use. A number of videos have been incorporated into “learning objects” on the concepts covered in the videos. These learning objects include links to online textbooks, explanations, links to relevant Learn ChemE videos\(^5\), and links to relevant videos. These are available for free through:

http://www.projects.bucknell.edu/LearnThermo/index.html

Limitations
It is difficult to evaluate cause and effect in a multi-institutional classroom study without completely isolating the subjects. Of course, this is not practical, so we present some potential confounding factors that may affect the outcome of the data. First, there is a plethora of learning materials for thermodynamics that could aid and assist student participants. We discount this possibility since the course instructors did not explicitly direct students to any of these resources, and we expect only the most intrepid of them to go out of their way to seek these out. Second, the authors could have employed a within-subjects design, where each cohort of participants would be divided into the four treatments (i.e. control, video-making, video-watching, and both video-making and watching). This was not possible since each of the institutions have relatively small class sizes, which makes creating several treatment groups not feasible. Additionally, the same instructor taught the course at each institution, which limits the variability in teaching styles, and resources provided. Finally, there is the possibility that students did not watch the videos at all. Although it is possible to monitor the number of views as well as determine which students opened the video from the course management system, it would be difficult to enforce compliance since students have the option to watch videos multiple times (artificially increasing the view count), or watch a video in a group (resulting in some students not “opening” the video through their account). The “video watching assignment” in Appendix B was used to encourage students to take video watching seriously, as it was part of graded homework for the thermodynamics courses.

Acknowledgements
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References
Appendix A: Video Creation Assignment

Professor X

Big show: end of class!

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 partner will gain a deeper understanding of two thermodynamic concepts and demonstrate mastery of those topics by explaining/demonstrating those complicated thermodynamic concepts to a broader audience of your peers and the public.

Project Description:
For two of the following concepts:
- Entropy & The second Law of Thermodynamics
- Reversibility
- Internal Energy vs. Enthalpy
- Equilibrium vs. Steady State
- The distinction between reaction equilibrium and reaction rate

Your team should produce the following:
Final product: Two polished 1-2 minute video designed to convey the core idea through an every-day metaphor or example and 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) for each of your two topics (two total videos). 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 a demonstration, 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 our class, 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. Please do not use any music, video clips, or images which are not your own or that are outside of “fair use”. If no one on your team is willing to appear, use animation, screen-cast, or another format for your video.

Intermediate Products:
1. An initial personal reflection of approximately one page, explaining your understanding of these concepts, at least one application of each concept in “real life”, and a reason why non-engineers should understand these ideas. To be emailed to Dr. Professor.

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

3. A rough-cut of your videos and written feedback on two other teams’ rough-cut (form to be provided).

4. A final written reflection on your product: what did you learn? did your understanding of the concepts change? How well do you feel they convey the central concept? This will be about 2 paragraphs long, and also turned in as an email to Dr. Professor.

Project Documentation Format:
Final: Export the video to a common electronic format (.mp4, .mpg, or .avi, for example) and submit to Dr. NAME as a) downloadable linked files in Google Drive, Dropbox, or Netspace OR b) on a memory stick. Hand in a cover sheet indicating: a) an outline of the answers to the points addressed in the videos 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:
- Monday, 3/30: teams assigned
- Friday, 4/3: Topic claiming starts
- Monday, 4/6: Initial written reflections due.
- Thursday by email, 4/9: One page summary plus storyboard/script for each video – email by 9pm Thursday, I will review and bring comments to class for 4/11.
- Wednesday, 4/15: Rough-cut (un/semi-edited video footage) due for feedback; feedback on other teams’ rough-cut due before midnight Friday 4/17 (email directly to other team, cc-ing Professor)

Teams:
Assigned, informed by student request (see upcoming email).
Grading: (each video is graded out of 100 points)
Technical (50 pts): Technical correctness, accuracy, clarity, and overall demonstration of conceptual understanding as demonstrated in the final project, grammatical and concise presentation of written work.
Visual (50 pts): Ascetics, video quality, visual quality, sound quality, 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:
• I have three last-generation iPads available for borrowing; can be used for shooting and editing video (simple options only through iMovie on the iPads) – These are complimented by microphones, a light, and a tripod that you can also borrow.
• The library equipment desk has several video cameras and microphones available for check out.
• Your phone may have sufficient video quality for this project (new iPhones, yes)
• I have two USB microphones available for borrowing
• Basement floor of the library has an excellent video editing lab (final cut pro and/or iMovie)
• The mac lab in BUILDING has iMovie which is relatively easy to use
• NAME our lab TA is available to help
Appendix B: Video Watching Assignment (online form in LMS)

NOTE – you will get several “video” homework assignments this semester. You do not need to follow the homework format for this question, but please use the online form to answer the questions.

a. Please watch three of the videos linked from the Moodle page before proceeding further. You may watch all four if you like, but you must watch at least three.

b. Please answer the following questions (web form)

Thermodynamics Video Feedback

Please use this form to submit your homework responses to video viewing questions. Your username (***) will be recorded when you submit this form. Not **?

* Required

Name?

1) Which topic were you learning about in today's videos? *
   - Enthalpy and Internal Energy
   - Equilibrium and Steady State
   - Entropy and the Second Law
   - Reversibility
   - Reaction Rate and Reaction Equilibrium
   - Other:

2) Before watching the videos, I understood this topic. *
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

3) Before watching the videos, I understood the relationship between the topics of the videos. *
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

4) After watching the videos, I understand this topic better. *
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

5) List four or five things you learned about this topic
6) What are some of the thermodynamic variables that affect this topic?
7) How does this topic relate to other things you've studied in this course or in other engineering courses?
8) What would you do to make a video that was more interesting and/or informative than the ones you watched?