Faculty-Led Videos of Real-World Industrial and Research Applications in a Materials Science Course

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Introduction

Using videos in engineering education is a common practice to enhance students' learning. For example, instructors often record lecture videos for students to review content if they miss class, and instructors often play open-source videos that provide additional resources for students to understand difficult concepts, supplement lectures, and/or prepare for exams [1]. Blended or flipped classes rely on videos for students to watch ahead of time to prepare for in-class discussions or interactive activities [2,3]. Lopez et al. [4] implemented an innovative blended-learning strategy that combines face-to-face teaching and self-assessment methods with video clips that provide detailed instructions for practical sessions such as labs for Elasticity and Strength of Materials. Overall, videos are a valuable tool to "disseminate methods, procedures, and results in science and technology fields" [5] and can also bring real-world applications to the classroom [6].

The objective of this study is to analyze the efficacy of incorporating real-world industry and research applications into videos on learning outcomes in an undergraduate junior-level materials science course. The videos are expected to engage and motivate students and to have them realize how theoretical concepts can be important in the real world. What makes this study different is that instead of using open-source videos, these videos show experiences in solving real-world problems in industry or academia of the instructors teaching the course. Two videos were produced that incorporated materials covered in lectures, including annealing, quench and tempering, yield strength, ductility, hardness, brittleness, precipitation hardening, corrosion resistance, steels, and nickel-chromium superalloys. The videos were designed by the instructors and directed and filmed by an experienced media producer on campus. The completed videos were shown in four sections of a course offered in Spring 2022, and a survey was administered to evaluate their efficacy. This paper details the process of producing such videos, key features incorporated in the videos to maximize student understanding and learning, evaluation methods, and results. The advantages, disadvantages, and lessons learned through this process are also discussed.

Development and Production of Videos

Selection of Real-World Material Science Applications for Videos

The real-world materials science videos were implemented into MEEN 360: Materials and Manufacturing Selection in Design, which is typically taken by mechanical engineering students in the Spring semester of their junior year. The course involves the selection of materials and manufacturing processes in design with an emphasis on material mechanical properties, microstructure production and control, manufacturing processes for producing various shapes for components and structures, and use of design methodology. Table 1 shows the topics covered in this course. Four instructors that had regularly taught the course developed a list of potential real-world examples for making videos based on their experiences in research and industry. From this list, two applications for the videos were selected; one involves improving polymer manufacturing devolatilization technology in industry, and the other involves reversing irradiation effects in an Inconel 718 beamline window from research work in collaboration with Los Alamos National Laboratory. As shown in Table 2, these real-world examples illustrate multiple technical topics covered in the course. These two videos were led by two instructors who were teaching the course in Spring of 2022.

Table 1: Materials Science Topics in MEEN 360

Topics/Chapters	Technical contents covered
Mechanical properties	Stress-strain curves, strength, ductility, toughness, hardness, fatigue
Stain hardening and annealing	Microstructural changes due to cold/hot working, annealing
Solidification	Nucleation, dendrite formation, cooling curves
Solid solutions	Basics of phase diagrams, solid solution strengthening
Dispersion strengthening	Eutectic phase diagrams, precipitation hardening
Heat treatment of steels and cast irons	Fe-C diagram, annealing, quenching, tempering
Non-ferrous alloys	Intro to common alloys: Cu, Al, Ni, Ti, etc.
Polymers	Intro to polymers
Ceramics	Intro to ceramics

Table 2: Material Science and Engineering Topics Illustrated in the Videos

Video 1 - Improving Polymer Devolatilization Technology in Industry	Video 2 - Reversing Irradiation Effects of an Inconel 718 Beamline Window
– Annealing – Quenching and tempering – Yield strength, ductility, hardness, brittleness – Polymer rheology and manufacturing – Diffusion – Viscous flow and stresses in pressurized components	– Non-ferrous alloys – Age/precipitation hardening – Annealing – Microstructural changes due to damage and annealing – Yield strength, ductility, hardness, brittleness – Nanoindentation (mechanical testing)

Video Development and Refinement Process

The videos for this project were developed in the multimedia facilities of the Engineering Studio for Advanced Instruction and Learning (eSAIL) at Texas A&M University. The procedure followed a standardized video development process that included meetings between the instructor and the senior producer for script development, script refinement, video filming, and editing.

The first step was for the instructor to prepare the contents for the real-world example in a PowerPoint format. Then, with the advice from the senior producer, the instructor turned the contents into a unique storytelling structure appropriated from broadcast TV as a news magazine-style program as outlined in Table 3. This type of structure provided a natural transition into an "investigative style" approach, providing the students with story details that used previously learned course content to see how to solve a problem. This structure created an anticipation element for students to actively engage. It also provided an accelerated way to present new materials without taking a long time to understand any difficult concepts [7]. The slides were also made more engaging by strict scripting, 2-D animations, and graphics design. Studies have shown that strong structures in lecture videos have a net positive effect on student learning by reducing extraneous contents and stimuli [8]. The project refinement used strategies that have been well established in the field, along with some refinement introduced by the experience of the senior producer.

Table 3: Storytelling Structure Template

Story Setup	1. Topic Intro - Real World Application 2. Problem Statement 3. Intro - Subject Expert 4. Lesson Title 5. Index of Referenced Lesson Topics 6. Industry History of Problem
Challenges	7. Preliminary Steps 8. Research Obstacles – Strategy Revision
Resolution	9. Final Outcome 10. Benefit / Summary

One major component used to produce the videos was that text narration of each slide was transformed from the traditional spontaneous lecture-style verbal instruction to strict scripting using a customized MS Word scripting tool. This tool facilitated revision/modification or addition to the original narration text to avoid grammatical issues such as redundant phrases and dangling prepositions. It also helped create short succinct sentences that improved presentation pacing and eliminated the slower fragmented delivery of a traditional classroom lecture. These steps resulted in shorter and more engaging videos [9].

The static graphics in the PowerPoint slides were redesigned as animations such that only relevant information was retained to avoid confusion and provide areas of focus for the students. More importantly, the instructor narration was "in-sync" using a simple "Say It / Show It" rule: vocal instruction must have a visual representation that correlates exactly with what is being discussed. This concept included using labels, data verbatim, and even on-screen transcription to eliminate the incongruency of saying one thing and showing another [4].

One technique used when there was no visual information was to employ a full-screen video or photo to showcase the on-screen text transcription of the narration instruction much like a graphic "storyboard." Another technique used was signaling, where a text overlay appears on either the right or left side of the screen that highlights important information displayed as text [10]. The videos show new visual information approximately every 10-15 seconds to ensure continuous engagement. This approach was aligned with the voice-over narration using the restricted word count of a customized MS Word script format. This detail prevented over-communication such as forcing the animation to “pause” before it could proceed because the narration had not finished.

In terms of graphic design, a simple design brand guide was used to provide uniformity to avoid slides with multiple layouts, different font sizes, colors, etc. Along with the story structure, the graphic design functions to tie everything together to produce a cohesive video that directs students where to focus their attention and minimizes the strain on their cognitive load. The video on “Improving Polymer Devolatilization Technology in Industry” [11] is 5 minutes and 25 seconds long which is within the 6-minute recommended time for this type of educational video for maximum engagement [9]. On the other hand, the video on “Reversing Irradiation Effects of Inconel 718 Beamline Window” [12] is 9 minutes and 5 seconds long, longer than ideal. Nevertheless, both videos are considerably shorter than if these real-world Material Science applications would have been presented as a typical PowerPoint presentation in a traditional lecture format.

Deployment of Videos

The videos were deployed during class in four sections (500, 501, 502, 503) of the course offered in Spring 2022. Table 4 provides information of each course section. Video 1 on the devolatilization of polymers was shown when “Heat Treatment on Steels and Cast Irons” was covered, and Video 2 on annealing of Inconel was shown when “Non-Ferrous Alloys” was covered. Afterward, students were given one homework question related to each video. For Video 1, the students were assigned an open-ended design-type problem, in which they had to recommend an appropriate heat treatment method for a steel gear to meet specific hardness and tensile strength requirements under certain constraints (e.g., dimensions and initial material conditions). For Video 2, the students were assigned a conceptual problem with a set of questions related to hypothetical stress-strain curves of an irradiated Inconel specimen.

It should be noted that the video-specific questions were integrated into a larger homework problem set instead of individual assignments to test their overall understanding of the concepts in a related topic. The expectation is that students will be able to connect new information (relative to what was otherwise taught in the course) from the videos to knowledge gained from the lecture component of the course, namely the effects of heat treatments under various temperatures and times and corresponding microstructural changes.

Table 4: Course Sections Information (T-Tuesday, R-Thursday)

Section	Student Enrollment	Meeting Times
500	100	TR 12:45 – 2:00 pm
501	57	TR 3:55 – 5:10 pm
502*	100	TR 2:20 – 3:35 pm
503*	97	TR 11:10 – 12:25 pm

*Section taught by one of the faculty associated with the videos.

Assessment Tools

Two surveys were conducted, one for the videos and one for the class at the end of the semester. The results of these surveys were analyzed with R version 4.2.2 statistical software using the Tidyverse [13], Likert [14], and Cowplot [15] packages.

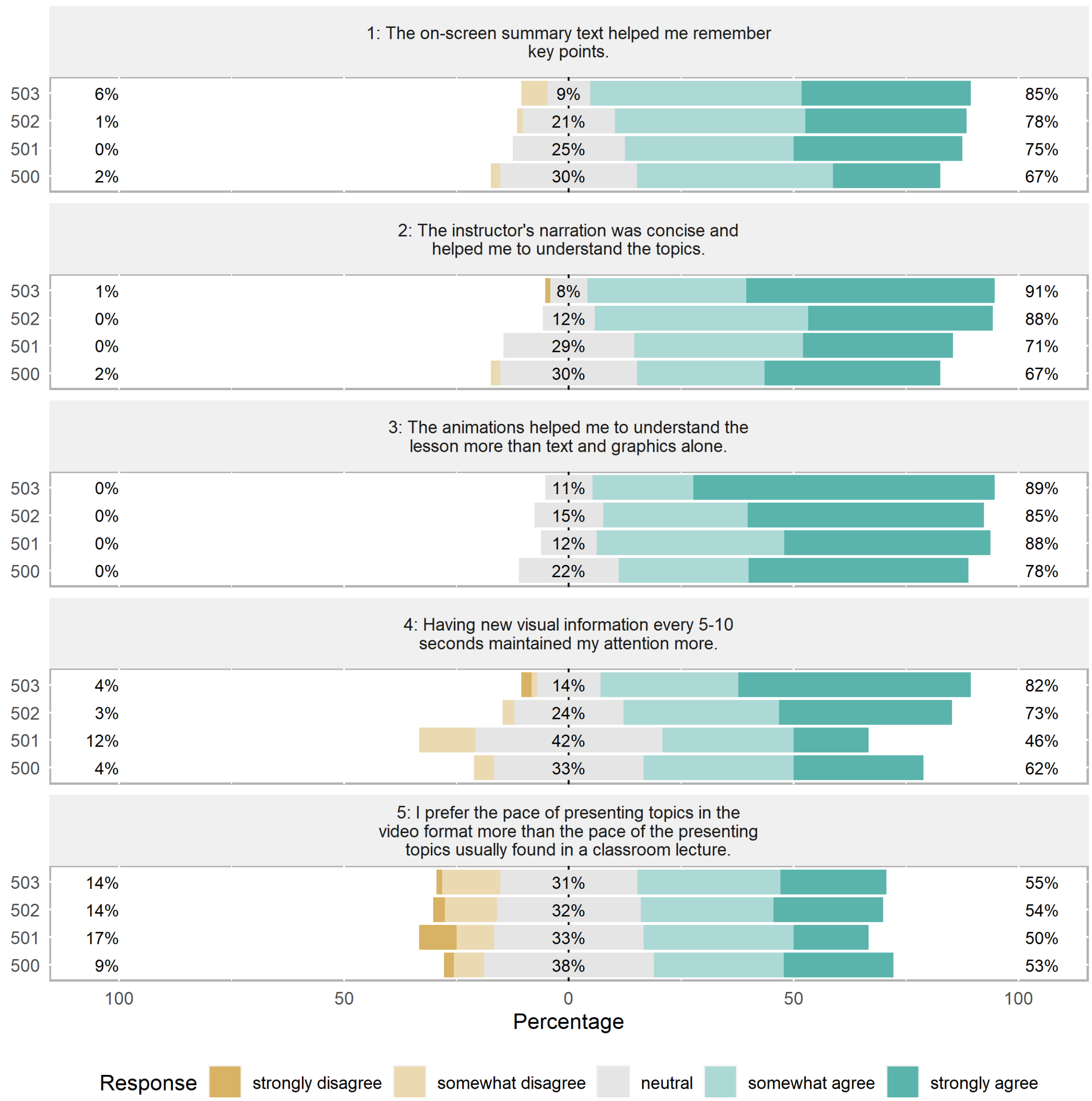
Video Survey

After the videos were shown in class, a survey containing five questions was created and implemented anonymously through a learning management system (CANVAS) to all sections of the course. The students completed the surveys voluntarily. The questions were designed to evaluate the effectiveness of the videos in facilitating understanding of the material using on-screen text to help remember key points, the use of concise instructor's narration and animations to help understand the topics and the lesson, changing visuals frequently to help maintain students' attention and student preference on the pace of presenting topics in the videos versus traditional lecture. The results of the survey questions are shown in Figure 1.

Overall, students' responses to the questions are very favorable regarding the videos, especially in the effectiveness of the videos to facilitate understanding using on-screen text, scripted narration, and animations to help understand topics. Regarding their preference to the pace of presenting topics in a video format versus a classroom lecture, their responses had a higher percentage of students being neutral or in disagreement. This correlates with previous studies that show students see videos as a supplemental tool and not a replacement of lectures [1]. Among the sections, there is a slight trend in the students' responses to questions 1, 2, and 4. Sections 500 and 501 have responses that are more neutral or in disagreement resulting in less overall agreement. These results seem to suggest there might be a favorable bias in the sections taught by the faculty in the videos (502 and 503).

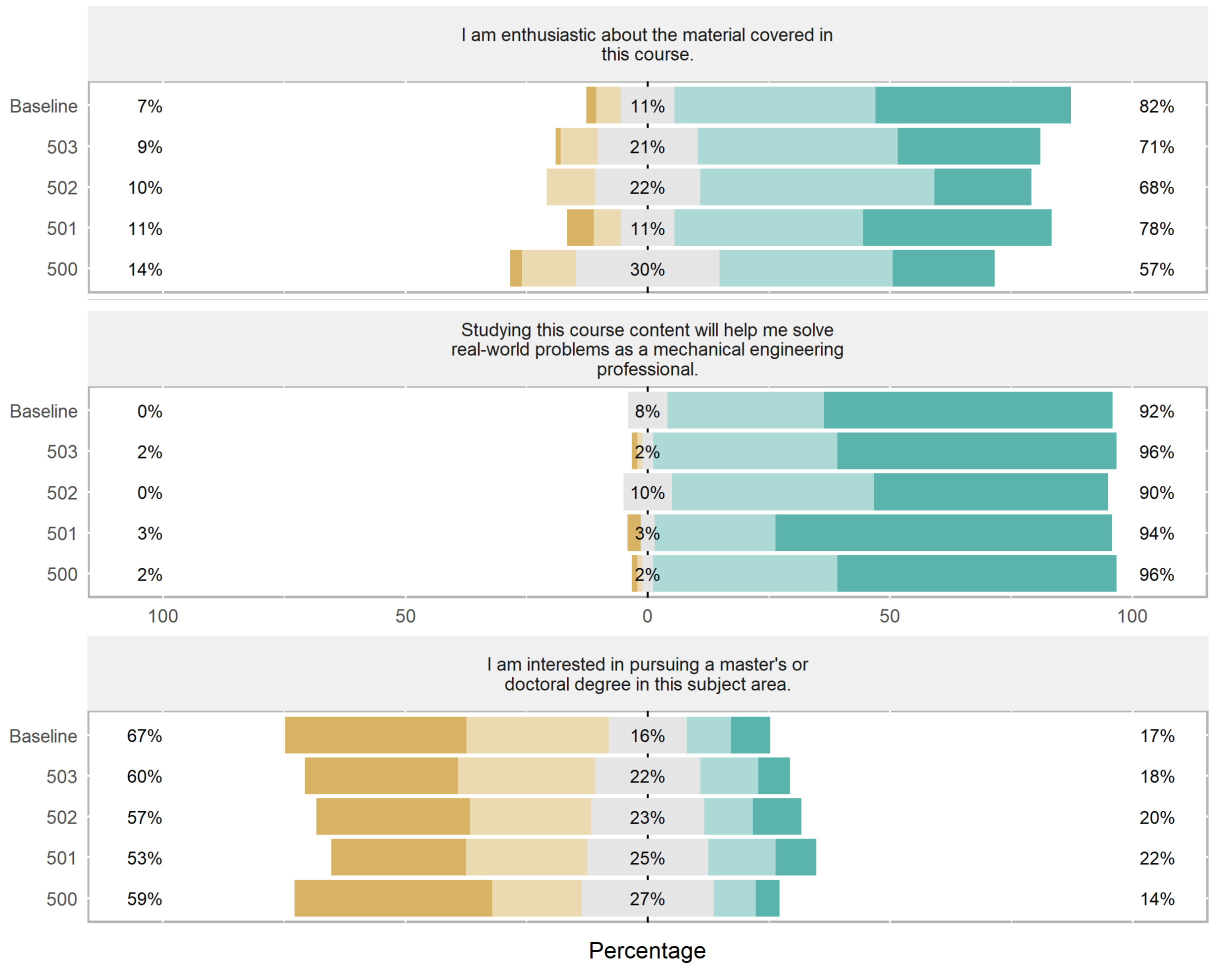
End of Semester Survey

A survey was created and administered near the end of the course that asked students to reflect on the course. The questions aimed to assess if the students were enthusiastic about the course, if the course helped in solving real-world problems, and if the students were interested in pursuing a master's or doctoral degree in the subject area. For comparative purposes, this survey was first administered as a baseline survey in a section of the course that did not implement the videos in Fall 2021, when significantly fewer students took this course (off-schedule group). The results are shown in Figure 2. Students' responses from all sections show some slight variations. Most think the course will help them solve real-world problems, and do not want to pursue graduate studies in the subject area. Most students are enthusiastic about the course although it appears the students from the baseline that did not see the videos are slightly more enthusiastic. On the other hand, students from section 500 were less enthusiastic compared to the other sections.



Student responses: 46 for section 500, 24 for section 501, 78 for section 50, and 85 for section 503.

Figure 1: Videos Survey Results.



Student responses: 99 for baseline, 81 for section 500, 36 for section 501, 60 for section 502, and 92 for section 503.

Figure 2: End of Course Survey Results

Discussion of Results

As seen in Figure 2, the videos did not seem to significantly change the students' overall perception of the course. Namely, certain sections that implemented the videos exhibited increases while other sections exhibited decreases in the various reflection questions relative to the baseline survey. As such, the results are inconclusive, which seems to imply that the videos did not have a large influence on students' overall perceptions of the course. This result may be ascribable to several conflating factors among the various sections, including different instructors, different course times of the day, etc. However, we posit that the most likely explanation is that these videos were only a few minutes each in duration. As such, other factors from the course more likely governed students' responses to these reflection questions than did the videos themselves. Additionally, this course shows numerous other videos (e.g., on YouTube) throughout the semester, approximately 1-2 per lecture. However, it is still interesting to note that the students' perceptions of the videos themselves were generally very positive (Figure 1). As such, we hypothesize that the influence of these types of videos will be more substantial in other situations, e.g., if more of these types of videos had been incorporated into our course or if we had instead implemented these types of videos into a course that normally did not already show any/many other videos, show connections to real-world problems, etc.

One of the major advantages of producing these videos is that they provide a very effective and efficient way to deliver content. Complex problems with multiple topics were presented in videos that were less than 10 minutes long. For example, there were 19 PowerPoint slides prepared for 5-minute video 1, which would have taken about 20 minutes to present in standard lecture mode. On the other hand, a major disadvantage is that it took approximately the equivalent of a two-week time commitment from the faculty to develop and produce the videos, plus the time of the senior producer. However, the procedures and tools that were developed can be used to train other instructors interested in introducing videos like these into their classes. Also, once an individual has gone through the process once, it should take significantly less time to make other videos. Another way to reduce the time to produce these videos is to cut the video session and only record the faculty narration.

The videos will be used again in future offerings of MEEN 360. However, instead of adding a question to their individual homework, the students will answer the question in class immediately after the videos are shown as an active learning activity. According to Brame [16], in addition to considering cognitive load and student engagement, the utility of videos as an effective educational tool can be maximized by incorporating an active learning component into the videos.

Conclusions

Two real-world videos that illustrate an industry and a research application were produced and shown in four sections of a materials science course offered in the Spring 2022 semester. The videos show a unique storytelling structure that utilized a natural transition into an "investigative style" approach, providing students with story details that used previously learned course content to see how to solve a problem. The videos incorporate techniques that maximize engagement and reduce cognitive load to maximize the learning experience. In general, the videos were evaluated very positively by the students, but the results were inconclusive in terms of their influence on students' overall perceptions of the course. However, these types of videos could be even more impactful in courses that traditionally do not show any type of videos nor explicitly relate technical content to real-world applications.

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