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Incorporating Multimedia Content to Enhance and Re-focus Course Delivery for a Multidisciplinary Engineering Laboratory

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Abstract

While electronic and on-line resources have made the remote delivery of lecture-based courses common place, the importance attached to the undergraduate laboratory experience has, in contrast, grown. Engineering-based knowledge is traditionally gained practically in educational laboratories[1]. Initiated in 1997, the Multidisciplinary Engineering Laboratory Sequence (MEL) at the Colorado School of Mines was created to provide students with a foundation in engineering fundamentals, skills to adapt to rapidly changing technology, and an aptitude for life-long learning[2]. MEL's educational objectives have been focused on experiments that span multiple disciplines, extend knowledge, and cultivate teamwork and leadership. From the beginning there were challenges to delivering a uniform curriculum. Instructors wrestle with a "hands-off" approach versus a traditional explain-all-the-steps approach to successfully develop a student's cognition (instrumentation and data analysis), psychomotor (apparatus operation and sensory awareness), and affective domain (learning from failure, creativity, and communication). Also, it has been observed that laboratory apparatus credibility and data relevance are critical, and perhaps essential, for students to successfully internalize their experience. Preparation in advance of an upcoming exercise is the key to student success, and efforts to encourage preparation have lasting returns.

There may be as many as seven laboratory sections for each course in the sequence taking place each week. Scheduling necessitates the involvement of several different instructors to staff the course, each bringing with them areas of expertise ranging from theory, to instrumentation, to data acquisition, to lab experience. The diversity makes the laboratory experience rich, but also presents challenges to optimizing course delivery to individual sections and the course overall. In an effort to enhance the student experience, short videos and slide presentations bringing together collective instructors' expertise were created to supplement the written introductions, descriptions, and pre-laboratory worksheets that have traditionally been provided. The resulting multimedia resources address multiple learning modes, accommodate the student's schedules, and provide a host of different means by which students can access the material. The ability to view the material multiple times and concentrate on challenging subject areas appears to be popular among students; it has increased efficiency and allowed for the expansion and growth of course content. The viewing statistics show that video modules are initially viewed prior to the lab period and, again, during the preparation of the final report.

This paper will explore the concerns and motivations that preceded preparation of multimedia content, outline thoughts to aid future production of effective course material videos based on experience gained, and offer a qualitative assessment of the changes in terms of the student experience and outcomes.

Background

The undergraduate educational laboratory is an essential part of the engineering development. In addition to developing valuable communication skills and working with a team, it is where students learn a scientific approach, develop skills working with technical equipment, and form the connections between theory and "real world" application[1] that will make them valuable to industry. To make the student's time and efforts worthwhile the lab experience should include growth in all of these components.

The Multidisciplinary Engineering Laboratory (MEL) at the Colorado School of Mines is a sequence of three, one semester long laboratory courses where students work with instrumentation, data collection, and analysis in practical subject areas that they might encounter in industry. MEL builds subject matter expertise in electrical circuits, fluid mechanics, and stress analysis and helps students understand relationships among science, engineering science, and engineering design[2]. The enhancements chronicled in this paper focus on the second laboratory course in the sequence, MEL II, which uses data acquisition systems and integrated computer hardware and software to conduct exercises that focus on Mechanics of Materials and Fluid Mechanics.

When the course was created founders envisioned that it would encourage the development of open-ended problem solving skills, by avoiding step-by-step procedures presented in traditional laboratory courses where students go through the motions to get the information necessary and "fill in the blanks" in a laboratory report without really understanding the material. In contrast, MEL students would be faced with a simulated industrial problem, are provided with a set of references, and expected to design their own experimental procedure...once in class, they assemble the apparatus, perform the experiment, modify their procedure, and report their results[3]. Today, while striving to maintain the founding tenets of the course, and recognizing that there were some unforeseen issues with the execution of weekly exercises, we seek to enhance the student experience by providing additional supplemental material in a video format easily accessible and accepted by students.

Problems Encountered

The lab's creators intended a typical lab period to begin with a brief lecture, 15-20 minutes, which might include theory, introduction to the equipment, and possibly some specifics about the material to be tested. During the remainder of the lab students would work from a self prepared procedure to conduct an exercise to demonstrate the engineering principle that is the subject of the week. The instructor and a graduate teaching assistant were envisioned to act as "coach" to the students through the experiments[2].

An overarching challenge arises simply due to the diversity of the instructing staff. Since the laboratory holds 24 students at a time and the program might be required to deliver the course to as many as 150 students per semester. This results in a need for up to seven individual lab sections. Scheduling and availability necessitates multiple instructors, each bringing to the lab a different personality and area of expertise. Some instructors have experience from lecture based courses and bring with them a strong understanding of the engineering principles while others, coming from industry, are attuned with the data acquisition equipment and instrumentation. Still others might offer a special mathematical expertise in data reduction and propagation of uncertainties. Although the diversity of the instructor staff makes the course strong overall, in terms of the student experience, it leaves individual sections lacking in key components. By creating videos that bring together these components, and making them available to all of the students in all of the sections, the breadth of knowledge can be offered to all.

Another challenge faced in the implementation of the MEL lab is more of a practical one. Students are not equally adept at the use of the lab equipment used for data acquisition. The course is offered to a diverse group of college majors which includes students from mechanical, civil, and environmental engineering with an occasional student from mining or petroleum engineering. The diversity exists on the instructor level as well with professors and graduate teaching assistants spread across the same fields. The unique collection truly enhances the lab experience but also creates challenges. From time to time students tend to become disengaged if they failed to see the real world application of an exercise to their particular field of study. The videos give us the opportunity to show illustrations and examples of applications from all of the fields to all the students.

Finally, we wanted to address a frequent complaint from students who have lost confidence in the equipment used in the lab. Although we are confident that the equipment used in MEL is adequate and reliable, students have expressed sentiments that their poor results were due to equipment that was faulty, unreliable, and frequently broken. Often this was not the case. The real reason for their failure to collect credible data was usually due to a wiring problem, a setup issue, or simply the time it took to begin collecting data. Although, the founders of the program envisioned a high degree of student independence during lab time and prescribed a degree of struggling to enhance the learning experience in practice it was observed that students reached a point of diminishing returns where they became bogged down and frustrated instead of challenged. Their learning experience diminished when the connection between theory and real world application could not be illustrated because the exercise was derailed during the procedure. The valuable part of the exercise realized during data reduction phase, analysis, and the effort invested in formulating conclusion was lost.

It has been shown that video-taped experiments can be a virtual substitute for distance learning students and are as effective as the traditional laboratory in attaining the desired course outcomes, and students' overall evaluation was very positive.[4] Our proposed solution is to use video supplemental material in conjunction with the traditional laboratory experience to provide adequate instruction to help students refresh material from lecture and effectively use the lab equipment to complete a meaningful exercise from start to finish.

Project Description

The project entails producing two video supplements for each lab exercise. One video will illustrate the engineering principle explored during the week and is intended to strengthen the tie between the lecture based course and real world applications. The second video supplement will illustrate the equipment setup and data acquisition portions of the experiment to increase the student's opportunity to collect meaningful data leading to a worthwhile experience during analysis and formulation of conclusions. The goals of the project is to level course delivery to the students so they benefit from the collective experience of the MEL teaching staff and increase the level of pre-laboratory preparation that each student is expected to complete prior to coming to lab and allow more class time open-ended exploaration into the exercise of the week. It has been shown that students prefer when class time is used for problem solving interactively with the instructor and prefer watching videos as opposed to reading written information. Students believe they learn better with more problem solving and shorter video instruction.[5]

A typical schedule for MEL II is divided between Mechanics of Materials and Fluid Mechanics each making up about half of the semester. Our project to enhance the course delivery was somewhat limited in terms of time so videos were produced only for the Mechanics of Materials portion of the semester. This approach afforded more time to be put into each video and allowed us to become familiar with the actual production of the material. In addition, a review as to the effectiveness and acceptance by the students could be undertaken before a commitment was made to produce similar material for the balance of the course. Actually, students taking the course during the first semester when video supplements were available would be uniquely qualified to provide a before and after comparison of course delivery since the new material would be available for the first half of the semester only.

Implementation

Short videos were created to supplement the existing written material that provided exercise introductions and descriptions. There would be two videos produced for each exercise that would include a review of the engineering principle to be explored and a brief introduction to the equipment setup and data collection. To make the videos attractive to the students they would be kept very brief, preferably four to five minutes, have a limited number of slides, and include an interesting mix of text, graphics, and embedded videos.

There are some known concerns associated with instructional video preparation, particularly associated with the lecture format. Visibility and clear communication of diagrams and equations written on the chalkboard or whiteboard has been shown to be challenging[6] To address this concern the traditional view of an instructor standing in front of a white board, marker in-hand, was not used. Instead, students would be shown short slides with interesting graphics, a modest amount of text, accompanied by concise, descriptive narration.

The preparation of each video included planning, recording, and editing. Even though we lacked professional production experience, the learning curve was much shorter than anticipated. The process began with a story board where an outline was produced to determine the order and extent to which each subject would be described. Sketches and scratches were used to create a logical flow of ideas, pictures, animations, videos, and text. Graphics that were needed were identified and a script was written. Slides were produced in Microsoft PowerPoint to allow for future modifications. Using a video editing software, Camtasia, voice recordings were made and assembled with the slides.

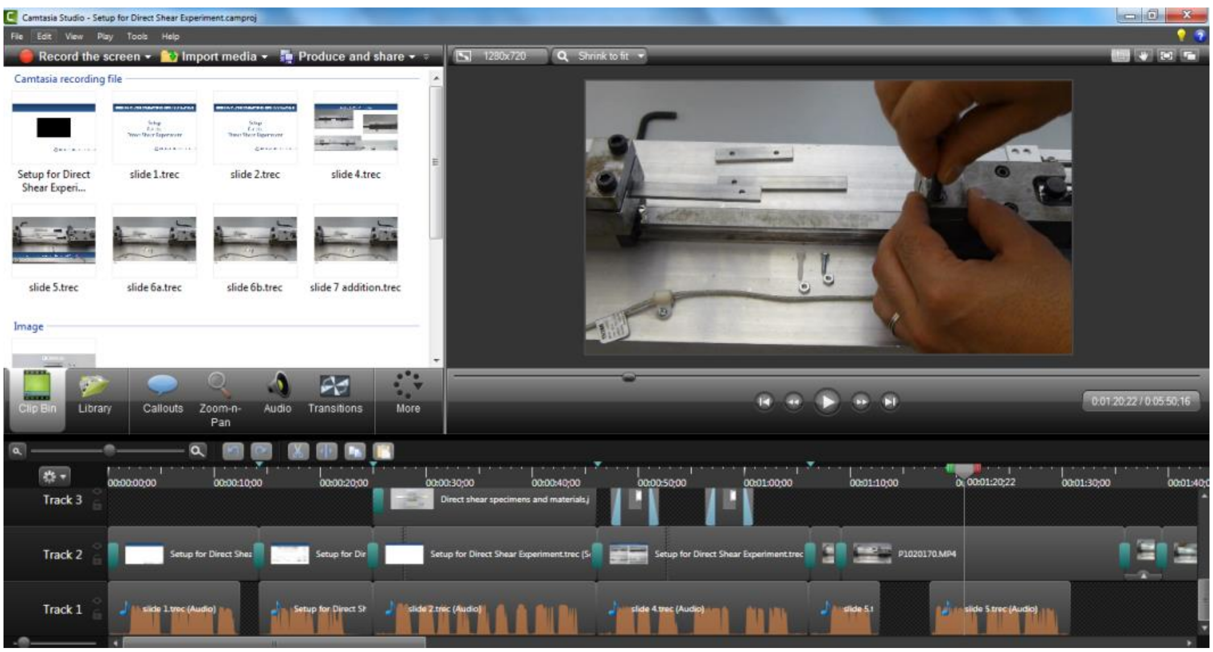

Figure 1 - Video Editing with Camtasia Software

When completed, the videos were uploaded to a private YouTube channel for students to access. A link to the videos was provided on BlackBoard, a course support website available to all the students, side-by-side with the written material.

Video supplements were produced for exercises that included helical springs, tension, buckling, direct shear connections, and strain gauges.

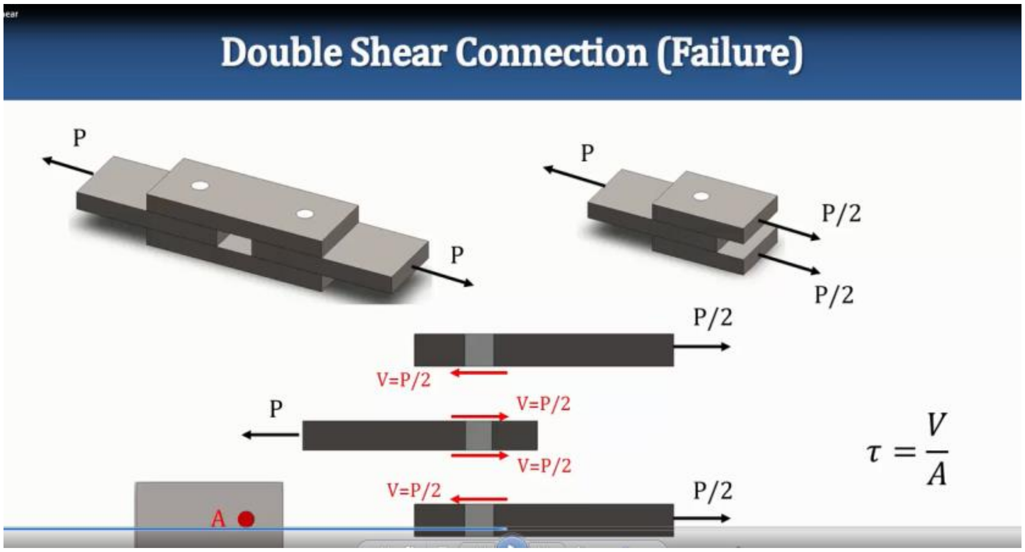

Figure 2 - Engineering principles illustrated for direct shear

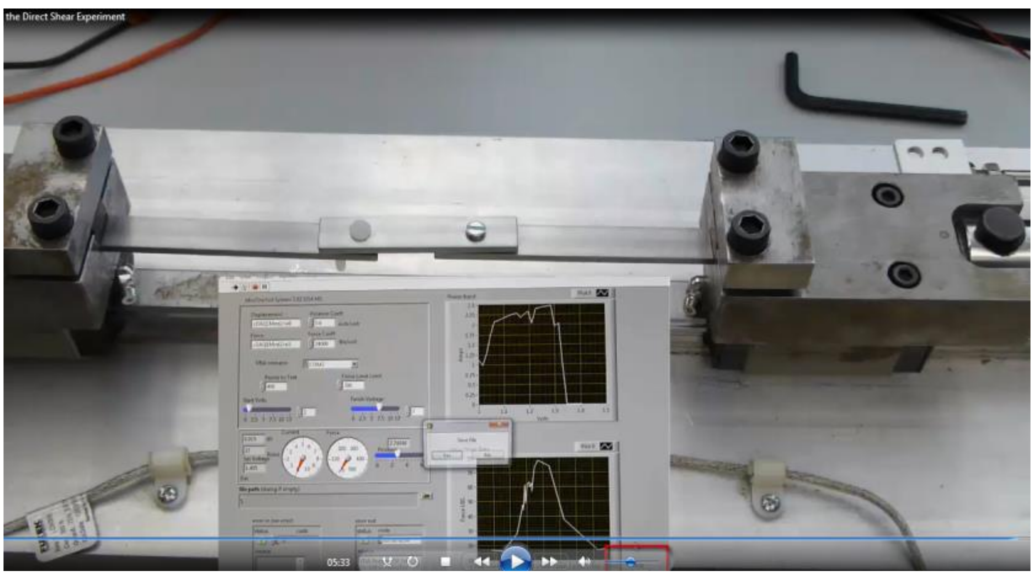

Figure 3 - Equipment setup and data collection for direct shear

Application/Feedback

Feedback was collected informally through several different sources. Some information was available in the course evaluations that are conducted by the school each semester. In addition, an on-line survey was done using Survey Monkey and viewing statistics were collected from data available on the YouTube channel.

The course evaluations collected by the school yielded some interesting information. In a typical evaluation students rate courses and instructors on content, delivery, and effectiveness. Additionally, there is a section at the end of the evaluation where students are allowed to give candid, anonymous, free responses. During the review of these evaluations it was noted that the new video supplements were mentioned many, many times. These unsolicited comments were encouraging and supported the reasons for undertaking the project. A sample of the comments included:

> *"The YouTube videos for the first part of this semester where really helpful. I was able to spend more time learning the content rather than trying to figure out how to set up the experiment."*
>
> *"YouTube videos were very helpful for conveying basic concepts as well as setup of the lab."*

Additional feedback was sought by using an on-line survey site, Survey Monkey (surveymonkey.com). The survey was given to all of the students in the first semester the videos were offered and, for comparison, students from the previous semester when the videos were not available. The survey was voluntary and the results and analysis are informal and non-rigorous but still very encouraging. The on-line survey seemed to show that:

- Students that took the course with and without video supplements had generally the same opinion as to the helpfulness of written material but those students with video believed video did a significantly better job reviewing the material, equipment setup, and illustrating engineering principles.
- Students accessed material before class, during class, during data reduction, and while writing reports, and during exam preparation.
- Students believed the videos shortened the time needed for lab preparation.
- Students with video supplements gave a significantly higher rating to reliability of the lab equipment.
- Students formed better connections between theory learned in lecture and practical application.

The on-line survey indicates that students value the video supplements as a good source for pre-lab preparation, they came to class better prepared, and the videos were used throughout the exercise. Responses indicate that while both groups seem to value the written material equally, the supplemental videos were significantly better received by the second group.

The on-line data also showed that the video material was viewed on laptops, tablets, smartphones, and other mobile devices as well as desktop computers which illustrate an increased accessibility to the material and a convenience not previously available.

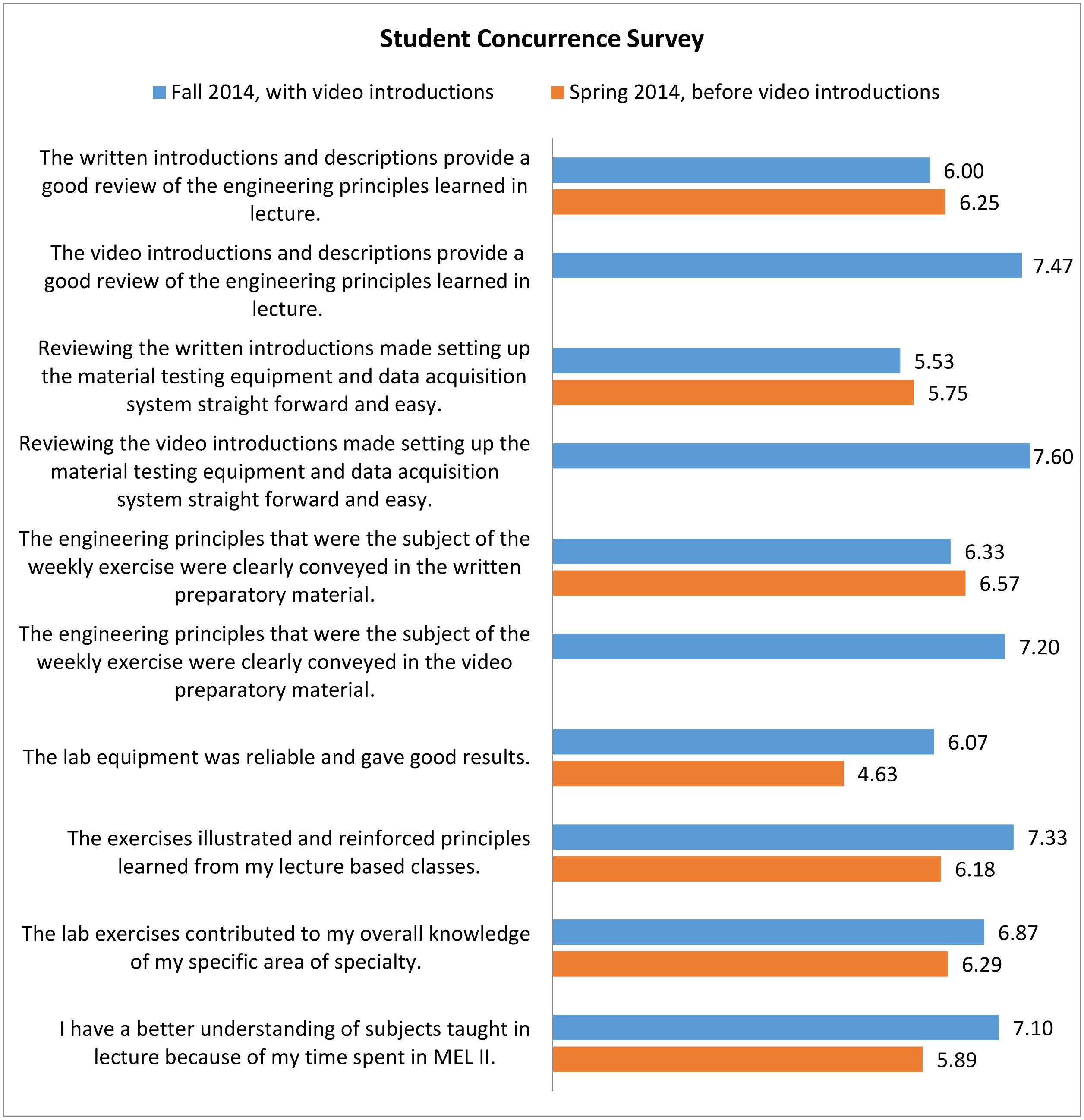

Figure 4 - Student Concurrence (1=Strongly Disagree, 10=Strongly Agree)

Data also strongly indicates that the videos helped reinforced principles learned in lecture and contributed to overall knowledge and better understanding of subjects taught in lecture. This is particularly important since it supports learning outcomes outlined in the course syllabus specifically to "build subject matter competency in fluid mechanics, mechanics of materials, data aquision systems and other associated subjects," and "establish connections between theory and practice." These results build department wide confidence that MEL II is reaching learning objectives and goals while effectively filling the role of a companion lab to lecture based courses of Fluid Mechanics and Mechanics of Materials.

Statistics tracked by YouTube were also interesting. During the first semester when the videos were offered, fall of 2014, there were six sections of MEL II accommodating 124 students. Keeping in mind the students work in groups of two and frequently view the material together, the statistics show that the video supplements were indeed very popular. For instance the video that illustrated the introduction to direct shear had 272 views and the introduction to helical springs was viewed 328 times.

Another source of feedback came from the instructors not directly involved with the production of the video supplements. Comments indicated that students came to class better prepared with a better awareness of what was expected of them. They noted decreases in the setup and execution time. Through the informal interaction with the students during lab there were indications that the depth of analysis was increased.

Conclusions

Overall, it appears from the feedback and informal survey results that the videos enhanced the MEL II laboratory experience of the students. The students gain exposure to the different aspects of the lab and benefitted from the collective expertise of the instructors conveyed to them in video form.

Video supplements, proven effective for lecture based courses, are an attractive means of delivering the course material for the educational laboratory. The multimedia approach is convenient for the students and increases the frequency of review and depth of subject matter studied.

Future Endeavors

The work completed for the existing schedule of exercises is only half done. We would like to build on what we learned and produce video supplements for the balance of the class where Fluid Mechanics is studied. In fact, from the course evaluations students expressed a need for this endeavor saying:

> *"Have youtube videos for the second part of this semester."*
>
> *And, "Produce videos for fluids portion."*

Beyond the completion of videos addressing the Fluid Mechanics exercises, continual improvements and enhancements of the existing material are always being contemplated. There are continual conversations of ways to improve individual exercises to make them more illustrative and interesting for the students. Regardless of what the specifics of future improvements might be, we will include a video supplements to enhance the student experience.

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