Learning Engineering Mechanics Through Video Production

Glenn W. Ellis,[1] Kathryn S. Lee[2] and Alyssa Tham[3]

***Abstract* - This paper presents an approach to integrating student-produced videos into an engineering mechanics class. Each student worked in a production team to produce a two- to three-minute educational video investigating a combined translational/rotational motion. Through this experience students expanded their communication skills by becoming familiar with the technical and creative skills of video production. They also expanded their understanding of mechanics by studying real-world applications and communicating their results. Throughout the project, students received extensive assistance from the college's media services staff—including workshops on managing and planning production, shooting and editing. Once the videos were completed, students were encouraged to reflect upon their experience through peer reviews and group reflections. Student feedback is presented and supports the success of the activity.**

Index Terms - communication, learner-centered, mechanics, metacognitive, video

INTRODUCTION

> Watch a student's eyes light up the first time they see the video from their camera appear on their computer screen for them to manipulate with professional effects, and you'll know you've just activated a student's imagination in a whole new way.
>
> --Nikos Theodosakis [1]

Educators, employers and the engineering profession are in broad agreement that a key element of engineering education is developing strong communication skills. Students typically learn about written and oral forms of technical communication—yet they often receive little or no preparation in the use of video technology for communicating technical ideas. This is the case despite the fact that video has become a primary communication medium in our society.

Little has been written about the use of student-produced videos for engineering education. In one related paper, Yew and Gramoll [2] describe the use of student-created multimedia presentations for conveying engineering concepts and techniques. However, more is written in the science education literature. Viglietta [3] describes an example of student-produced videos for scientific inquiry and provides key points for success in the classroom. King [4] provides a historical overview of the development of the motion picture as a tool for science education. The technology is traced from its beginning as a silent motion picture through its current manifestation in videotapes and videodiscs in science education.

Of particular interest is the work of Reynolds and Barba [5]. They present how the use of video technology is helping to change the emphasis to student-centered learning in the science classroom. According to the authors, this occurs because students are provided with more options for knowledge processing and also because of a shift in control within the learning environment from the teacher to the student. They describe the following advantages for using video technology. First, video allows students to control time and study phenomena that are difficult to observe. By increasing or decreasing the speed of action and allowing repeated viewings, students are able to confirm and observe details that were previously missed and dramatize the change process. Second, they discuss how seeing visual and auditory representations can bring sense to verbal descriptions of scientific phenomena. Finally, they contrast the use of commercially prepared instructional videos with the immediate and direct connections to the concrete world that's provided by student videotaping.

TEACHING ENGINEERING MECHANICS

The Picker Engineering Program, established in 2000, is the first engineering program at an all-women's college in the United States. In addition to educating technically competent engineers, this program also aims to educate socially conscious engineers who will integrate engineering with the sciences and humanities. To deliver the content of this curriuclum most effectively, the Program supports new approaches in the engineering classroom.

This paper presents the use of student video production in Continuum Mechanics I, EGR 270, a four-credit, semester-long course that is largely populated by sophomore engineering students. The aim of the course is for students to develop a strong conceptual understanding and problem-solving skills in a variety of topics related to the mechanical behavior of a continuum. Topics include 2-d and 3-d rigid

[1] Glenn W. Ellis, Smith College, Picker Engineering Program, Little House, Northampton, MA 01063 gellis@smith.edu
[2] Kathryn S. Lee, Smith College, Media Services, Neilson Library, Northampton, MA 01063 kleel@smith.edu
[3] Alyssa Tham, Smith College, Picker Engineering Program, Little House, Northampton, MA 01063 atham@smith.edu

body equilibrium, shear and bending moment diagrams, dynamics, vibrations, and an introduction to stress and strain. The delivery of content in the course is based upon learner-centered pedagogy and is discussed in Ellis et al. [6,7].

A fundamental concept in EGR 270 is that conservation of linear and angular momentum can be applied to analyze a variety of engineering situations. This requires that students bring a solid understanding of Newtonian mechanics to the class. Although the students have been exposed to these ideas in their introductory physics course, they typically do not see the big picture of how it all fits together, nor do they have sufficient experience in applying the concepts to real world situations. To help them develop a greater mastery of these ideas, EGR 270 begins by helping students learn to use a conceptual framework to structure their physics knowledge. The framework developed for the class is presented in Ellis et al. [7,8] and has been shown to be effective. The purpose of the video production project presented in this paper is to provide an opportunity for students to apply the knowledge framework so they can understand complex, real-world situations. A second major objective of the project is for students to learn to communicate through the video medium.

PROJECT ASSIGNMENT

During the first week of the course students organized themselves into video production groups of four students each. Their assignment was the following.

> In this project you will produce a 2-3 minute video that instructs future EGR 270 students about the motion of an object. Through this process you should learn about using video as a communication tool, as well as apply and demonstrate your understanding of dynamics... The subject of your video is the motion of an object. This can be any object of your choosing such as a diver, volleyball, space shuttle, etc. In the video you must teach your audience about the mechanics that describe the motion of that object.

The deliverables of the project included a 1-2 page proposal due one week after it is assigned. In this proposal students presented the title of the video, the motion to be investigated, the instructional strategy to be used (voice over, interview, vignette, combination, etc.) and a brief narrative describing what will appear on screen. Five weeks after the project assignment, each group was required to submit their video with a script/storyboard. To make the criteria for success clear to the students, they were provided with the grading rubric at the time of the assignment. Also, in the video production classes described below, students were shown a sample video that was produced to illustrate the characteristics of success described in the rubric.

Item	Description	Points*		
Script	A sufficiently detailed scripted/script was prepared in a timely manner. Planning showed attention to particular characteristics of the video medium. The script shows creativity in the approach to making the video.	6	4	2
Editing	Technical and aesthetic choices made in editing contributed to the effect of the video. Editing is used effectively to communicate in the medium. The video is concise and carefully constructed.	3	2	1
Audio	Technical and aesthetic choices made about the audio contributed to the effect of the video. All dialog is audible. Background music and sound effects contribute to the effectiveness of the piece.	3	2	1
Visual	Technical and aesthetic choices made about the visuals contributed to the effect of the video. Camera framing and camera moves show careful planning, execution and communicate effectively. Graphics are legible and effective.	3	2	1
Mechanics Correctness	Concepts presented are completely correct.	3	2	1
Mechanics Depth	Video displays a deep understanding of mechanics.	3	2	1
Topic Creativity	The topic choice and use of mechanics in the video are interesting and original.	3	2	1
Mechanics Clarity	Concepts are clearly presented so that viewers may acquire *insight* into the topic.	3	2	1

*Columns are for distinguished, proficient and developing.

FIGURE 1
RUBRIC USED TO GRADE VIDEOS IN EGR 270

To help students with the production aspect of the project, Smith's Media Services provided a series of three video production workshops, supplied camcorder equipment and editing facilities, and provided post-production assistance to students working in the Services Digital Media Lab. Although it was only required for one member of each production team to attend each workshop, most students decided to participate in all three.

The first workshop, *The Video Production Process*, introduced students to video management planning. Topics included how to develop, research and present ideas; select and work with contributors; acquire and use visual and audio materials; write storyboards and scripts; and explore deployment options and copyright issues. In the second workshop, *Video Production II*, students were introduced to the technical aspects of production including: tripod setup and adjustment; use of the camcorder's basic control buttons; and a review of microphones and lighting techniques to assure quality recording. Finally, in *Techniques of Editing*, students used iMovie [9] to import video, work with video and sound clips, add transitions, titles and effects, and export to tape, DVD, or compress to QuickTime.

The workshops were designed to acquaint students with both the artistic and technical skills needed to fully utilize the video medium. An emphasis on the artistic side of the production is consistent with Smith's philosophy of integrating engineering and the liberal arts. It is interesting to note that the workshop instructor saw a marked difference between the engineering students and students from other programs in the college. She found that engineering students were more inquisitive and not only wanted to know how to operate the camcorder, but also wanted to understand the physics and engineering principles underlying its operation. For example, students asked questions about how the light was captured on the CCD, transformed into an electrical signal and then encoded as a magnetic pattern on tape. One student even requested a spare camcorder that she could take apart and put back together again.

STUDENT VIDEOS

Within the parameters of the project assignment, students exhibited creativity and originality, both in content choice and presentation style. They often chose topics based upon the personal interests of the team members and this added to their enthusiasm. Videos were produced on the following subjects: shooting billiards, bicycling, rolling various objects, basketball, automobiles on banked turns, figure skating, and diving. A variety of approaches were used to script the videos. For example, some videos placed an emphasis on including short clips of interviews that they conducted with content experts. Other videos relied upon a storyline to provide structure for the video. A common technique used in most of the videos was to freeze the motion and use equation and graphic overlays to illustrate the free-body diagrams or equations of motion (see Figure 2). Through this technique they were able to analyze and communicate the mechanics at a particular moment and then integrate that moment with the overall motion.

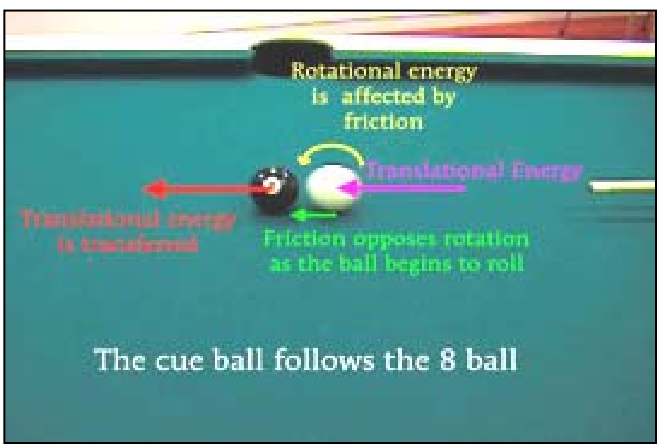

FIGURE 2
SCREENSHOT FROM A STUDENT VIDEO EXPLAINING THE MECHANICS OF SPIN IN BILLIARDS

VideoPoint [10] software was made available to students to allow them to mark screen locations and then plot motion graphs from those markings. Figure 3 shows a screenshot of a foul shot. VideoPoint was used to mark the locations of the ball's center of mass and then to plot its horizontal and vertical velocity and acceleration graphs as a function of time later in the video.

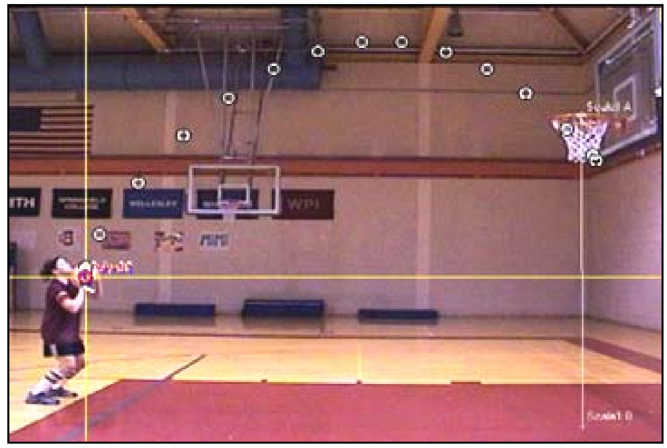

FIGURE 3
SCREENSHOT FROM A STUDENT VIDEO EXPLAINING THE MECHANICS OF A FOUL SHOT

Students immediately grasped the technical aspects of camcorder operation and recorded stable, focused, and color balanced video. Use of external microphones for interviews and narratives provided clear, audible tracks to accompany the visual material. Music and sound effects were used effectively to accentuate the videos' scripts. For example, in "Spin – A Keen Look At Angular Momentum" the student producers used a 10 second clip of a popular song, 'You Spin Me Right Round' by the group Dead or Alive to set the tone for their instructional narrative. In "Engineering Students Behind the 8-Ball" the crack of a pool ball break and music from The Sting created an engaging opener for their video.

Careful shot composition enhanced the video scripts. For example, in "Is Falling Really Free? A Look at Air Resistance" student producers selected a professor with expertise in fluid mechanics as an on-camera expert. The students chose a medium close up shot that was slightly angled up with key elements of the shot composition on intersecting lines (applying Rule of Thirds). Thus the expert appears on the right of the screen and equations on the whiteboard are shown at the left. A slight upward angle lends credibility to the subject's explanation of drag resistance—i.e. he is an expert because he towers above the norm.

In "Know Your Bike" the students used a variety of camera shots, positions and moves to create a visually appealing production. A spinning wheel mounted on a wall in a local bicycle shop, an angled shot up of the bicycle shop owner in the foreground with bicycles suspended from the ceiling in the background, and pans of various riders on bicycles all indicate creative thought given to shot selection.

PEER REVIEW AND SELF REFLECTIONS

After the videos were completed, part of one class period was used to watch all of them. Students were required to write down at least one aspect of each video that they thought worked well and one suggestion for improvement. These comments were then given to each production team. Based upon a review of these comments and instructor feedback, each production team reflected critically upon their production experience and submitted a written group reflection.

In the reflections students discussed all aspects of the project from technical points such as lighting, camera angles, sound and graphics, to more artistic points such as capturing viewer interest or pacing. Students also frequently discussed management issues and in particular they discussed the dynamics of how their group interacted during the project. It is also interesting that in almost every reflection the teams wrote about the experience as a personal success. The following are a few excerpts from these reflections.

One group, recognizing the delicate balance between education and entertainment, commented:

> Our group has learned that a good video must grab the audience's attention in the introduction and maintain its interest throughout the production. Though our introduction and theme helped maintain interest, the use of background music would have made our explanation more exciting. Also, while our diagrams and equations were helpful aids, they could have been presented more slowly, so that they would be easier to understand. The video should have a steady flow, with numerous clips and transitions that lead into one another and do not interrupt the movie's pace.

Many of the reflections discussed the importance of choosing the correct amount of content and pacing. Peer feedback was often useful in this process. For example, one group wrote:

> During the production, we were slightly worried that we were over explaining a simple concept. Peer reviews, however, assured us that using a slow and simple presentation allows our audience to understand the concepts being presented.

Also common were reflections that discussed how the members of production teams learned to improve their group skills. One example is the following:

> The group learned how to accommodate each member's individual schedule, cooperating during meeting times to be most productive, and accepting diverse opinions in a mature fashion. All these skills will be applicable in future professional settings during internships and eventual careers.

Finally, several groups discussed issues related to teaching and learning. One of them wrote:

> Video producers should take into consideration that not all audience members will share the same learning styles. Therefore, the video should accommodate as many learning styles as possible.

ASSESSMENT

A variety of assessments including pre- and post-course attitude surveys, a mid-semester formative assessment and post-course written surveys were administered in EGR 270 for the 2002 and 2003 classes. Based upon the 2002 data (the 2003 showed similar results), Ellis et al. [6] reported that the learner-centered approaches used in the course were highly effective for increasing student understanding, confidence and commitment to a career in engineering. In 2003, two questions about the video production project were added to the mid-semester survey.

The first question asked the students if the video project was helpful for their learning. Of the 41 students surveyed, 34 (83%) indicated a positive response, 6 (15%) did not respond or indicated no preference, and 1 (2%) indicated a negative response. The following were cited multiple times as positive factors in the experience:

- the satisfaction of learning the skills needed to communicate through a new medium;
- the opportunity for creative expression in an engineering course;
- the intellectual challenge of communicating ideas;
- the chance to learn on their own; and
- the experience of working in a group.

One individual wrote the following:

> Not only did we learn an entirely new medium of communication and presentation, but we also gained invaluable practice in working effectively in group situations. For our particular project we wrote an engaging and informative script, learned how to frame and compose specific video shots, mastered several editing techniques, and learned how to incorporate several technical programs into one medium.

Several students commented on the peer review and group reflection process. One wrote:

> After reviewing feedback from fellow engineering peers, our production apparently left an impression of being original and funny; however, more emphasis should have been put on quality recording. This project has definitely been a valuable lesson and for the trouble we have gone through we can assure a superb next video!

The only negative response was that the project required too much time. (Students reported that they spent an average of 23 hours researching, scripting, recording and editing their video projects.)

The second question asked the students for ideas to improve the video project. Fewer students chose to answer this question. Those that did respond overwhelmingly expressed an interest in using more powerful editing software instead of iMovie. Other suggestions included increasing the time period for producing the video, allowing more freedom in topic selection and providing an opportunity for revision.

DISCUSSION

> Teachers have long known that asking students to teach is a powerful technique for helping them learn. Asking students to produce a video that will help other students learn something not only excites them with the opportunity to work with technology, but it also challenges them to think hard about the topic at hand and how best to organize and express the information in ways that a specific audience will understand.
>
> --Tom Wolsky and Bronwyn Rhoades [11]

Ellis et al. [6] and many others have reported on the success of learner-centered approaches in the classroom. Providing an opportunity for students to work together to choose and research the subject of their video; learn a new communication medium through hands-on experience; use their video to teach each other students; give and receive peer feedback; and then reflect upon the experience are clearly elements of a learner-centered activity. Helping students to become knowledgeable about the learning process and developing a community of learners in which students and faculty learn from each other are important elements of EGR 270 and the Picker Engineering Program. Video production is one way in which this can be accomplished. Students were clearly excited by the chance to work with the medium, but many reported that the challenge of how to communicate their ideas to teach others was the most stimulating and rewarding part of the project. This was particularly evident in the group reflections that discussed issues related to teaching and learning.

Although research has shown that all students benefit from the use of sound pedagogy, women and underrepresented minority groups are particularly at risk in the typical engineering classroom. Goodman et al. [12] summarize the concern of engineering education reformers as follows: "the interests, socialization, and experiences of women (and other underrepresented groups) are often at odds with traditional engineering structures. These populations tend to flourish, on the other hand, in settings that emphasize hands-on, contextual, and cooperative learning." Clearly producing an educational video meets this description and the positive student response supports its success. There is also reason to believe that producing a video may support retention by increasing the confidence levels of women engineering students. Reynolds and Barba [5] have reported that students who videotape themselves have an increased self-confidence in their abilities to perform in front of others. It is interesting to note that EGR 270 students commonly referred to the project as a "personal success," possibly indicating increased confidence.

In spite of the fact that all students participating in EGR 270 were women, we believe that video production is an effective activity for all students. First, as discussed earlier, the project is consistent with the research on learning for all students. Second, the literature has shown that the use of video technology is gender-neutral. For example, the UC Irvine, Department of Education showed that the positive effects of video technology in education were strikingly similar with varying groups of student populations and in different sites [13].

Integrating a technically complex project such as video production into a course can be a management challenge. We have found that an important element for successfully implementing the use of video was a close interaction between the EGR 270 instructor and the Media Services staff. This began well before the course started and included planning a project time frame that allowed for maximum equipment availability and media support, collaborating on the creation of a grading rubric and support materials, and developing a relevant sample video that illustrated the potential of the medium. Later during the course that interaction proved to be critical again when evaluating the videos.

Planning has already begun for improving the project in the future. In response to student feedback, the focus of change will be on removing the technical barriers to producing higher quality videos. The most important change will be to replace the iMovie editing software. Students found the simplicity of the software to be too restrictive for animating Photoshop layers, combining various video clips on a single screen, and sound editing audio clips. Given the choice for future productions, a majority of students preferred professional video editing software such as Media100 or Final Cut Pro. Also in response to student feedback, a second improvement will be to make available the use of an audio recording booth to self-record digital narration and links to buyout libraries for background music and sound effects.

CONCLUSIONS

The production of student videos using peer feedback and group reflections is an effective learner-centered strategy for learning introductory engineering mechanics and the video communication medium. Student feedback indicated that it helped them improve their communication skills while learning about mechanics. Many students also reported improved group skills and increased attention to learning issues. The positive student response is consistent with research on effective learning and retention of women and underrepresented minority groups in engineering; thus we feel that this activity is broadly applicable in engineering education.

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