Lights, Camera, Engineering: Energizing and Motivating Students to Enhance Learning

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Abstract

Engineering classrooms are an ideal setting for the dramatic presentation of material. Dramatic presentation can include using multimedia content, employing surprise, humor, dramatic voice, exciting physical models, and other non-traditional, highly engaging presentation techniques. These techniques seize the attention of the students and are phenomenal tools in increasing student understanding and illustrating applications of the course material. Often, course material is presented to students without a tie into pragmatic, real world application. By making physical models and dramatic presentation techniques standard practice, instructors bring practicality into each lesson. Students have consistently given positive feedback to this effort through mid-course and end-of-course feedback surveys. Taking engineering out of the often intimidating realm of the theoretical and bringing it into the real world enables instructors to engage students in the “whys” and not just the testable bottom line.

Introduction

Drama in the classroom creates an environment where students look forward to attending class. Through a variety of staged events throughout the course, instructors involve the students in very non-traditional education opportunities (Hanus and Estes, 2002). This is accomplished through props, video clips, music, and demonstrations related to the lesson objectives. This “intellectual excitement” keeps students engaged for the entire class allowing interaction, discussion, and continuous feedback leading to better understanding and the opportunity to explore the subject matter in greater depth (Lowman, 1995). Bringing drama into the classroom requires a significant amount of preparation to enable smooth and practical application and must be fine-tuned and highly coordinated to be an enabling tool (Hanus and Estes, 2002). Without proper preparation, dramatic presentations can waste class time and diminish the time available for solid classroom instruction. In the worst case, poorly executed drama can even detract from learning or undermine the instructor’s authority.

This paper describes examples and results of drama, multimedia, and demonstrations implemented in the ABET accredited Civil Engineering program at the United States Military
Academy (USMA) at West Point. With constantly improving technology, music and videos are now easier to bring into the classroom and many teachers at USMA and elsewhere have seen great gains in student participation, engagement and retention when integrating such media into class sessions. When used correctly, adding drama to the classroom has proven extremely positive and makes the classroom environment fun and effective for both the instructor and the students.

**Course Specifics**
Mechanics of Materials (CE 364) at USMA has many of the same objectives as most introductory courses in solid mechanics. The course introduces stress and strain, and examines the stress and deformation due to axial, torsional, bending and other loading conditions. One difference, however, is the lack of any previous “Introduction to Engineering” courses, many of which are taught at other institutions at the freshman level. Thus, CE 364 is the first course at USMA in which students encounter design in a meaningful fashion. This increases the challenge of keeping students engaged, since design procedures and concepts are taught essentially simultaneous with the introduction of the theory. Further, because the number of engineering courses is lower than most institutions due to large number of required humanities courses in the core curriculum at USMA, the number of topics covered is somewhat higher than in most introductory courses in mechanics. The combination of these factors is the primary driver in pushing our instructors towards increased student involvement and engagement. The instructors for this course vary in age, experience, military service, and educational background. Half the instructors are active duty military, while half are civilians. Educational backgrounds range from construction management, to geotechnical engineering, to structural engineering.

**Evaluation Technique**
The manner in which data was collected and conclusions were drawn was primarily based on student responses in 3 surveys. The first survey was collected halfway through the semester and asked very general questions concerning the strengths and weaknesses of the course. The second survey was given at the end of the semester and contained very detailed questions regarding specific techniques used by instructors in class. The manner in which the questions were asked gave us insight into the students’ perceived effectiveness of our techniques as well as actual recollection and application of material. The questions were open response, multiple choice, or involved ranking the effectiveness. We attempted to vary the question format (ask for physical model or ask for concept) and the sequencing in order to prevent leading the students to their answers. The third survey was electronic and every course and student at USMA participated. This survey was useful to compare students’ attitudes across all courses in the department as well as the entire school. All students remained anonymous to encourage honest feedback.

**Multimedia: Music, Video and Movies**

_a. Music_
A majority of music used was to create a relaxing and familiar atmosphere in the classroom. Music was played consistently before class for 10 to 15 minutes. As students walked down the hall they could hear the music and distinctly know it was their classroom. As the semester
progressed students brought CDs into class to ensure the proper music was played for their generation and taste. The music very often spurred conversation before class. As an example, the band O.A.R. was playing before class early in the semester. This band was very popular with the students and a conversation started over the upcoming O.A.R. concert at West Point. Soon 10-12 students were discussing the concert details and forming groups to buy tickets and sit together. Many of these subgroups became lab partners and study groups as the semester progressed.

On one occasion, music was used to directly drive home an engineering concept. The lesson involved the intricacies of steel column design. The concept that was difficult for students to remember was that columns buckle about the “weak” axis, in this particular course the Y-Y axis. Before class, Judy Garland’s classic Wizard of Oz song was playing in the background, “Somewhere Over the Rainbow.” To the students, this song was merely a terrible choice to satisfy their taste in music.

Later in class during a discussion of the driving mechanism of buckling failure, the instructor asked the class “the area moment of inertia about which axis will drive the design of a long column?” The students mulled it over and proceeded to answer the question just as predicted: mixed. Some students confidently answered “the X-X axis, I_{X,X}” while others said “the Y-Y axis, I_{Y,Y}”. After some deliberation between the students and no solid conclusion the instructor said, “Hold on, hold on, I’m hearing valid points from all of you. How can we settle this? I know! Let’s see if our good friend Judy Garland has the answer!” Immediately eyes started to roll and students were getting prepared for the next “cheesy” trick.

The instructor began to play the nostalgic “Somewhere Over the Rainbow” tune starting from a pre-determined location in the song. As the students listened to the song, their heads were swaying with the tune and some lips were singing along. “Birds fly over the rainbow… why oh why can’t I?” Immediately the students began to groan. The instructor boomed, “It’s I_{Y,Y}! Judy Garland knew all along!”

b. Video Clips
Due to advances in technology, video clips have become extremely easy to show during class using overhead projectors and computers with DVD capability. Video clips were used to both grab students’ attention before class and enhance the point being made for the particular lesson.

An example from class involved showing a vehicle test video that was testing guard rail failures and bumper crash tests. The slow motion film showed materials failing under a given load. The point brought out was that sometimes engineers want systems to fail under a predicted load. For example, sign posts should shear off when struck by a vehicle at a certain speed. It becomes critical to find the principal stresses and know material properties to determine when materials fail. The video clearly showed to the students that engineers can and do use the concepts taught in mechanics of materials.

Another example used in class was a video clip from “Dumb and Dumber” to introduce the concept of strain. The scene was when Harry tried to lick the ski chair lift and got his tongue stuck. His friend Mary tried to pull his tongue loose. His tongue stretched to an unlikely length
before it was freed from the chair lift. The students could relate to this movie and really enjoyed the change of pace even though it was merely a 2 minute clip. As soon as the clip was over the instructor displayed the slideshow below:

![Longitudinal Strain](image.png)

\[ \varepsilon = \frac{\delta}{L_0} = \frac{L_f - L_o}{L_o} \]

Figure 1: Dumb and Dumber illustrates the engineering concept of strain.

A student was chosen to physically measure the initial length of Harry’s tongue and the final length. Using the change in length divided by the initial length, the class used the fundamental equation for calculating strain. Harry’s tongue was not a typical material used in construction or machinery, but that was not the point. The point was to relate a change in dimension to a new concept of strain, which the “Dumb and Dumber” clip did very well.

**Stage Props: Demonstrations, Rolling Slides, and PowerPoint**

Throughout the semester, we used assorted “props” in order to grab student attention and to keep them actively engaged. These props worked on several levels: teaching engineering principles, gaining student attention, and changing the classroom pace. Different styles of non-multimedia “props” include visual aids and demonstrations, introductory slideshows, and Microsoft PowerPoint presentations within a specific lesson. Students favorably rated the props that we used during the semester both in terms of their liking the additional effort as well as helping them understand a concept.

**a. Demonstrations and Visual Aids**

Throughout CE364, we attempted to bring engineering to the students with demonstrations and visual cues they could easily recognize from their own experiences (Marchese, 1998). We worked to tie in-class example problems and worksheets to real world structures they could reach out and touch (Klosky and VanderSchaaf, 2002). For example, consider test or homework problems on shear and moment diagrams with multiple applied distributed loads and mid-span couples and imagine trying to visualize that beam “in the wild.” Below are two case studies: a spectacular success and an equally spectacular failure.
The most successful demonstration and visual aid in CE364 was “hot dog day.” To illustrate the underlying principles in thin walled pressure vessels (TWPV), we distributed cooked hot dogs to the students in class. This helped them visualize that hoop stress is the mechanism of failure in cylindrical TWPVs. The setup and presentation varied widely between instructors (eating leftovers out of garbage after complaining of missing breakfast or lunch all the way to pictures of the Oscar Mayer Weiner-mobile as an introduction). The lesson began with the normal discussion and drawings explaining the theory and reasons behind TWPV and then we distributed the cooked hot dogs and had a free form discussion of how the theory worked in the actual hot dog case. We pre-split the hot dogs and then over-cooked them in a microwave oven to ensure we had the correct visual image in every case. We also wrapped individual hot dogs with bun in aluminum foil for each student. The time required to setup for an 18 student class (20 hot dogs total) was approximately 20 minutes.

By far, the least successful demonstration or visual aid in CE364 was the “compression cadet”. The “compression cadet” demonstration illustrates compatibility of deformations by compressing a student. The setup is a 2x4 board with a student holding a “pin” at one end (metal dowel through a pre-drilled hole), a bungee cord from the room ceiling as a redundant reaction, and a student (with hardhat) bolted to the bottom of the board as the final reaction. A lightweight (known only to the instructor) concrete block is hung from the end of the 2x4. The 2x4 deflects downward at the free end (the block), but maintains a straight line from the student pin to the free end. The preparation for the class involves preparing the 2x4 and the reactions as well as the worksheet for the students. The demonstration allows for a change in pace, drama when the large block is about to compress the student, and discussions about compatibility of deformations (the main purpose) as well as redundant reactions and design.

Figure 2: The “compression student” had no noticeable impact on student learning.
b. Rolling Slideshows

The rolling slideshow technique developed out of the desire to create a welcoming environment at the beginning of class. It can be used as an alternative or complement to playing music before class. The concept was to have something scrolling on screen that could spark student interest and start conversations in the time before class when students were coming and settling into class. The subjects we used varied widely, ranging between military photos, research project pictures, the “demotivational poster” series, slides on engineering failures, and most commonly slides that illustrated the topic of the lesson.

A particular student favorite was a rolling slideshow on the Tropicana parking garage collapse in Atlantic City, New Jersey. The students had already seen the story in the news and were excited to be able to discuss the details in class. When they showed up for class and saw the slideshow running, the students began discussing everything from design to construction to engineering ethics. They immediately became concerned if they could be liable someday for their engineering. The images they saw in the slideshow really brought home the importance of precision and being thorough. Discussions drifted into constructability concerns and actual causes. Each class section came up with a number of possibilities for the collapse to include improper formwork practices, and engineering errors. As reports started being released, another slideshow was shown before class describing the most likely cause of failure as determined by professionals in the industry. The students were intrigued. They realized that despite being very young engineers, they made many of the same conclusions as to why a structure failed!

Figure 3: Real world examples to illustrate the big picture.

The preparation time for each slideshow was typically under two hours. Note that this time cost is heaviest up front. Once the slideshows are developed, they can be used for multiple semesters with minimal changes. Rolling slideshows are simple to create and develop; the time investment is primarily required to find the pictures (and includes the inevitable sidetracks that result from internet searches). Each slide appeared for up to 20 seconds, had minimal text, and attempted to grab attention. There were typically 7-10 slides per slideshow running in a continuous loop. The
slideshows tried to illustrate multiple examples in order to hit the civil, mechanical, aeronautical, and non-engineering majors. For example, strain gages are used in a wide variety of applications and a simple internet search found pictures of strain gages on bridges, ships, aircraft, teeth, and other places.

c. Slideshow Presentations In-Class

We attempted to avoid using slideshow presentation of engineering content in class as much as possible. However, we felt that the material could best be taught using the technological advantages of PowerPoint presentations in the two cases below. In both cases, we focused on the interactive nature of the material and used the slideshows to reinforce this. Other cases where we successfully used PowerPoint included diagrams or tables that required special highlighting or in class usage, such as choosing a beam from a beam table or finding stress concentration factors.

The most interactive PowerPoint presentation used a game show format in order to explore material properties. The standard worksheet involves an overlay of several material stress-strain curves and asks a series of questions to determine material characteristics (hardness, strength, resilience, etc). By investing the time to create and animate a PowerPoint presentation of the worksheets, the lesson became very interactive. Students were broken down into teams and had to answer the questions (write on board) and then ring in first to answer. Points were assigned arbitrarily and the overall winning team won cheap and meaningless prizes (candy, pork rinds, etc). The capabilities of PowerPoint allowed for display of the basic curve and then specific questions would appear through animation. The correct answers could be graphically shown so that everyone could see “why” the answer was correct.

A particular slideshow success story involves the “The Amazing Strain Train.” Based on a simple sketch from the course director, the final version mutated into a multimedia extravaganza as each instructor personalized the slideshow. The premise behind the lesson is linking stress and strain through Generalized Hooke’s Law. An animated train moved from “station to station” in route to its final destination. PowerPoint allowed for animation complete with a train whistle each time it started moving. The instructors embellished the story and claimed the raw strain data side was similar to the undeveloped Wild West, and the refined principal stresses side was similar to the sophisticated East. The separation between the two was Generalized Hooke’s Law or the “continental divide” or “Hooke’s Pass” the wastelands that have maimed many previous students. Each time the train left a stop the instructor yelled “all aboard!” and the students replied “the strain train!” The connecting mechanism is train tracks between the stations (no express routes) resulting in a railroad known as the “Strain Train”. The students filled in boxes with material they knew or developed over the lesson. The lesson was enjoyable, complete with train whistles, choo-choo jokes, and general embarrassing behavior. While the students still struggle with Generalized Hooke’s Law, they all have a very visible response to the Strain Train running joke. As Hooke’s Law reappears in multiple lessons, the gag carries on and continues to be reinforced.
Student Response and Results

Overall, the response in the surveys was extremely positive. Students recognized the “entertaining, yet educational” nature of the demonstrations and visual aids at the same time they realize that the music and video clips are “nice touches” and stimulate them.

Multimedia applications in the classroom served a variety of functions. The most common use was merely to grab the students’ attention and get them engaged in class, vice providing actual course content. This technique enabled students to feel more comfortable in class, attracted their attention, encouraged them to engage, and resulted in their learning engineering more effectively. In these cases, the multimedia used did not deliver engineering content, but provided an avenue to get students in a better frame of mind to learn. However, multimedia was also used very effectively to directly teach engineering principles. The course lent itself well to employing a wide variety of multimedia.

In the anonymous survey taken at the end of the semester, 100% of the 109 students surveyed stated that they felt welcomed by the music before class. The music before class did not promote direct learning of engineering. However, two very useful outcomes did result. First, the students felt welcomed and at-ease at the start of class and it made this class stand out from others. In fact, students exposed to music before class rated it 7.5 out of 10 for “making the class memorable and different from other classes”. Secondly, the students found a common bond in listening to the music. They began to form sub groups in the class and planned to be together outside of class time. This resulted in educational benefits; students were encouraged to work
together in groups and the more time they spent together the better they worked together on future tasks.

The Judy Garland “Somewhere Over the Rainbow” technique, despite the students’ outward mocking, worked well. On the following homework and even the final exam students wrote “Column buckling, Y oh Y can’t I, I Y-Y” and proceeded to design their column using the appropriate area moment of inertia. This song yielded two results. First, the students were able to apply an engineering concept through a means other than rote memorization. At the end of the semester 73% of the students recalled the song “Somewhere Over the Rainbow” and related it to column buckling and using the weak axis as a driver. Second, they developed a common bond, pretending to dislike the works of Judy Garland.

The overwhelming response from students was that videos grabbed their attention, facilitated them building a greater understanding of concepts, and helped build rapport with the instructor.

In class demonstrations and props proved to be well worth the effort—89% of the students responded with “hoop stress” or “thin walled pressure vessel” to the question, “What was the main concept on ‘hot dog day’?” This question was asked free form and the students could write any answer. Hot dog day was over two months prior to the survey. More importantly, on the final exam, well over two thirds of the class passed the questions on cylindrical and spherical TWPVs.

The “compression cadet” proved less effective. While students seemed to enjoy watching a classmate get compressed, the demonstration took at least 15 minutes of class time and provoked a flat reaction. Not one student responded correctly to the question, “What demonstration illustrated the idea of compatibility of deformations?” One student responded with an actual example we had lying around the room (a slice of metal pipe filled with concrete), but if the student wrote anything in response to the question, it was a guess at a different physical model we had used in class. Not even the students who were compressed got the message. A potentially more effective (and simpler) demonstration may be a block of foam that can’t support a textbook until a few strands of spaghetti are added. This provides a visual link to reinforced concrete columns using materials that they don’t think could possibly support a weight.

Student response to the rolling slideshows was very positive overall. Notably, most students responded that they liked the slideshows because they showed the big picture and real world applications of what they were learning. The students appreciated the spontaneous nature and enjoyed the pragmatic application. It validated their many hours of study.

On the final surveys, the Strain Train received multiple, unsolicited comments. Although the students claimed this was also “cheesy” it was very effective. Students referred to the “strain train” many times over the course of the semester to recall the lengthy process of converting strain to stress.
Overall, demonstrations and visual aids were the most effective at giving a better understanding of the material, although in-class PowerPoint presentations were also effective. Demonstrations, visual aids, and video clips all rated high for grabbing attention and getting the students engaged in class as well as getting them excited about coming to class. Note that while class attendance is mandatory, enthusiasm is certainly not. As far as making the class memorable and different from other courses all four categories (music, video clips, demonstrations and visual aids, and PowerPoint presentations) cumulatively averaged over 5 out of 10 describing the class as memorable. Students recognized that music and/or rolling slideshows created a welcoming atmosphere at the beginning of class.

While these results show the trends, it’s important to recognize that each class had its own personality and preferences. Some of the sections showed a much stronger preference for the diversionary music and video clips or didn’t respond as well to the in class PowerPoint presentations. It is also notable that the demonstration / visual aid scores for the instructor who had used them before generally received above a 9 / 10 score—practice does help sell the drama.

An interesting result of the course involved very similar feedback from students, despite the diverse backgrounds of the instructors. The techniques described worked across the spectrum of teaching and engineering knowledge and experience. Notably, student response for all instructors maintained the same pattern, showing that these techniques can be implemented regardless of experience.

**Conclusions**

The dramatic presentation techniques and stage props that we used in CE364 grabbed and retained student interest as well as helping with student understanding. Primarily, we validated the following ideas:

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<th>Delivers Engineering Content</th>
<th>Makes Class Memorable</th>
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Figure 5: Effectiveness of techniques in stimulating “intellectual excitement”
Overall, if the techniques used did not directly deliver engineering content, they made the students enjoy being in class. In accomplishing such, we contend that the students were enabled to learn more effectively.

Bibliography


Biography

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