Shock and Awe in the Civil Engineering Classroom

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There's No Drama in Engineering!

When one advocates using drama to breathe fresh life into a college classroom, engineering is not the first subject that comes to mind. Law, history, and political science seem much more likely candidates. Law offers a natural source of conflict and resolution as major issues are argued passionately by both sides and a jury or all-powerful judge decides the outcome; there are clear winners and losers. History is the story of dreams realized, wars fought, nations formed, and a perpetual competition for resources. Political science relates how nations organize, make decisions, and establish policy. All of these activities feature exciting tales of backroom maneuvering, powerful personalities, and unpredictable events. These subjects naturally lend themselves to suspense, intrigue, and compelling stories. Engineering, on the other hand, is the application of scientific theories, imposition of an organized and mechanistic thought process, and demonstration of conservative and responsible behavior. Hollywood knows. They make movies and television shows about cops, doctors, lawyers, corporate villains—sometimes even about teachers and soldiers—but almost never about engineers. If an engineer ever did appear in a movie, it would probably be Tom Hanks screaming, "There's no crying in baseball and there's no drama in engineering." But he would be wrong.

Why Bother?

The purpose of this article is to show that, despite conventional wisdom, there is a multitude of wonderful and exciting opportunities to bring drama into the civil engineering classroom. The skeptic might contend, "My purpose in the classroom is to impart knowledge. I am not an entertainer." Oh, but he is, even if he does not intend to be. Wankat and Oreowicz (1993) contend that "all lectures are performances." Joseph Lowman (1995) makes the comparison that, "college classrooms are fundamentally dramatic arenas in which the teacher is the focal point, like the actor or orator on stage." Lowman concedes that a teacher can be competent without performing, but "the ability to stimulate strong positive emotions in students separates the competent from the outstanding teacher." Such positive emotions can come from humor, spontaneity, variety of activity, animated delivery, enthusiasm for the subject matter, and the presence of drama in the classroom.

At its best, drama can enhance interest, add emphasis to a key concept, and improve retention of a critical learning point. At worst, even if dramatic elements do not relate to learning the topic at hand, they will make students more attentive. Too often, an engineering class becomes entirely predictable and routine as detailed procedures are followed to solve problems. Tauber and Mester (1994) point out that "predictability breeds contentment while the unexpected breeds attentiveness." Contented students become complacent and overconfident and often stop thinking. Well-orchestrated drama creates a tension that forces students to actively think and ask why. Students learn more effectively when more of their senses are engaged. Well-executed drama has an emotional impact on students' senses and can even cause slight physiological changes (i.e., heartbeat, eye movement, breathing).

Surprise

Tauber and Mester (1994) contend that effective drama relies on either suspense or surprise. Surprise depends on unexpected events—occurrences that shake previously held beliefs or cause some degree of cognitive dissonance. Students are forced to resolve the dissonance, which requires them to think critically about a subject they had heretofore taken for granted. Achieving surprise might appear difficult in the world of engineering, where the goal is to apply predictable and universal laws to the world around us, but Wankat and Oreovicz (1993) state that dramatic effect in the realm of engineering is natural because "there is an inherent drama and majesty in the ability of theory to predict and occasionally miss the behavior of the real world."

Typically we teach engineering by covering the theory and using examples that illustrate that theory. There are usually exceptions to the theory, and those become opportunities to introduce drama in the form of surprise. Similarly, the theory often includes some assumptions that simplify the complex world into something that is more manageable. These complications can be used to defy expectations. A dynamics course offers many such opportunities:

- The unbalanced wheel (Fig. 1) catches students off guard as the instructor releases it on a ramp and the wheel rolls uphill.
- A Wilbur force pendulum (Fig. 2) is another example. The instructor provides a downward displacement and releases the pendulum. The mass on the spring initially moves up and down, but gradually starts to twist. Eventually the twisting

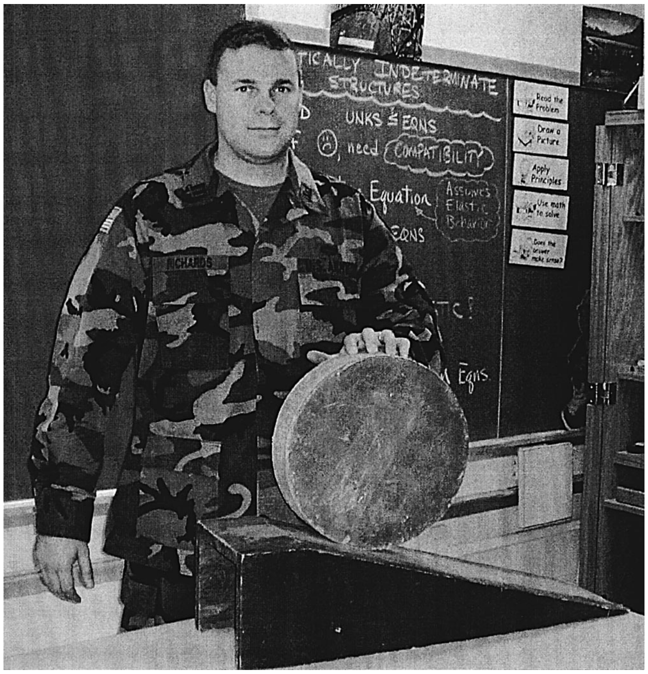

Fig. 1. Students are surprised when the professor releases the unbalanced wheel and it rolls up the ramp.

motion dominates to the point that all vertical movement ceases. The vertical displacement then starts again as the cycle repeats itself.

- Resonant frequency demonstrations, whether illustrated with a washing machine, a rolling wheel, or vibrating masses, provide surprising results to those seeing them for the first time.

The degree of surprise attained is often more dependent on the presentation and acting skills of the instructor than on the physical event itself. And those skills are greatly affected by prior thought and preparation—which in turn requires effort and time.

Surprise can be introduced merely as a change of pace to hold students' attention. Lowman (1995) suggests that student attention spans are short and that some change in format is needed

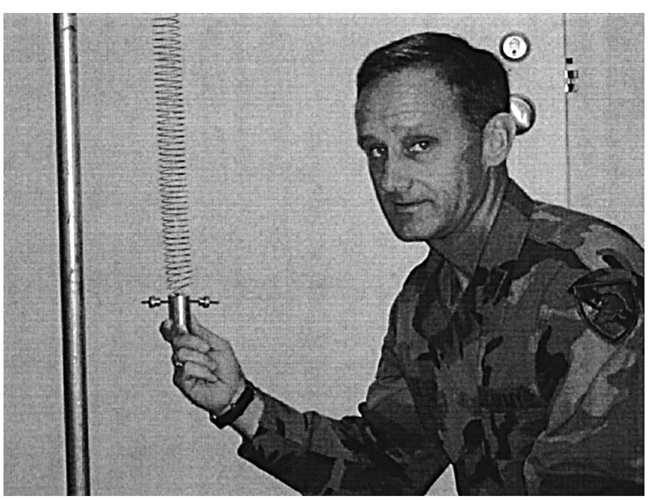

Fig. 2. Student interest is piqued as the Wilberforce pendulum is released and cycles through phases of pure translational and pure rotational motion.

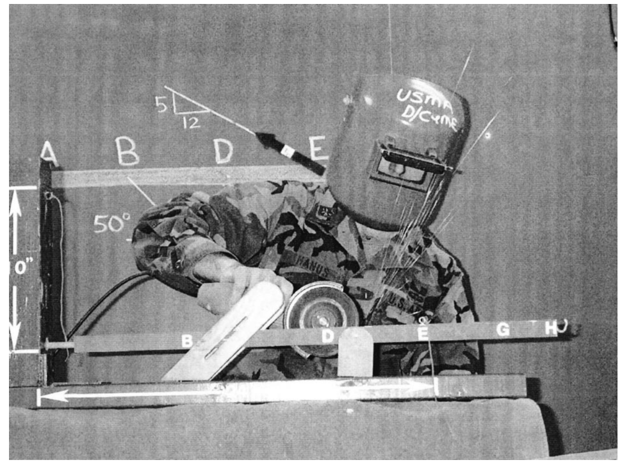

Fig. 3. Instructors enhance the use of the free-body demonstrator by using progressively more outrageous power tools to remove the constraints.

about every 10 min. This surprise can take the form of an unexpected slide in a presentation, a sudden rearranging of the desks to a new configuration for an activity, or merely making everyone stand for a specific purpose. The "normal-force aerobics" exercise introduced in last issue's Teaching Lessons Learned column is an example. Students were required to stand and lean forward on the balls of their feet and then lean back on their heels to illustrate that the normal force is not necessarily located at the centroid of a body. Beyond the inherent learning value of the demonstration, students are engaged by the unexpected requirement to stand up in the middle of the class.

One of our favorite (and most infamous) uses of drama in a Mechanics of Materials lesson involves hot dogs. A *thin-walled pressure vessel* typically fails along its longitudinal axis due to hoop stress, as illustrated by the way a hot dogs splits when it is overcooked. As the instructor explains this to her students, she notices that one of the janitors has left an old hot dog in the classroom trash can. (This is, of course, purely theatrical; she actually placed the hot dog in the trash can immediately prior to class.) The effect is enhanced with flour and green food coloring to simulate mold. The students are legitimately shocked when the instructor plucks the hot dog from the transh can and takes a bite. The students are surprised further when she departs the room and returns with a tray of fresh hot dogs, one for each student. As the students enjoy their hot dogs, they can hardly overlook the fact that each one is split along its longitudinal axis. The effect is memorable. A decade after graduating, many former students tell us that they vividly remember the concept of hoop stress in thin-walled pressure vessels (a fairly minor point in the overall course of instruction), because of the hot dog demonstration.

Once drama is established, it can feed upon itself. In our Statics course, instructors use a "free-body demonstrator" (Fig. 3)—a physical model that includes all of the supports (hinge, roller, fixed support, slotted roller, and cable) that the students will need to understand in subsequent structural analysis lessons. This device is used to demonstrate the creation of a free-body diagram. The instructor successively removes each physical support from the model and replaces it with its corresponding reaction forces on the free-body diagram. Long ago, an instructor feigned a struggle with removing the fixed support, as if it had somehow become jammed. In a deadpan manner, he reached into the desk drawer, retrieved a hatchet, and violently chopped the dowel that

Fig. 4. A lesson on mass moment of inertia is built around the big race between Steel Wheel and Rolling Timber.

Fig. 5. The class applies the work-energy and projectile motion equations to determine the firing distance for the flaming catapult.

held the body to its support. The stunt was so well received by faculty and students that instructors have since expanded upon the idea, using grinders to take out the pins, propane torches to cut the cable, and even a chainsaw to cut the final constraint. The students are surprised and remember it.

Suspense

While surprise happens quickly, suspense develops over time and builds as an event or story unfolds. It piques curiosity, often builds to a crescendo, and leads to a satisfying end result. Both surprise and suspense require planning and a keen sense of timing for success. Engineering classes are filled with discovery, and in most cases the students do not know the answers in advance. The situation is ripe for suspense. The key is to generate sufficient interest in the situation that students will give it serious thought—to hook them on the plot. By making connections to their past experiences and education, teachers can entice students to postulate an answer. Finally, the instructor can carefully and selectively provide clues that allow the students to stumble upon the right answer themselves.

Entire classes can be built around the development of suspense. Our Dynamics course provides two examples:

- The first is a lesson on *mass moment of inertia*—a topic that is not inherently exciting by itself. The class begins with some well-orchestrated hype for a big race between Steel Wheel (a hollow steel cylinder with a solid wooden core) and Rolling Timber (a hollow wooden cylinder with a steel core), as shown in Fig. 4. Their weights and overall dimensions are the same. The students place their bets and predict the winner. As the buildup continues and just before the starter's pistol fires, the instructor halts the race and states, "Let's talk about this for a minute." The class discusses how moving mass away from the axis of rotation increases resistance to rotation. The skater who brings her arms against her body to spin faster is a familiar illustration of the concept. A student standing on a rotating platform can be used to demonstrate the same phenomenon in class. Midway through the lesson, the instructor asks if anyone would like to change their bets and prepares to resume the race. After a similar buildup, the instructor again halts the race and proposes that it is possible to compute the mass moments of inertia for the two competitors. The computations clearly indicate which cylinder should win the race. The instructor concludes the lesson by finally conducting the race. As expected, Rolling Timber emerges victorious. Even though the outcome is now beyond doubt, the student's curiosity has been piqued, and the professor would risk a riot by not running the race.
- A second example applies the work-energy equation to a model catapult. As students enter class, the opening battle scene from the movie "Gladiator" is playing on-screen at the front of the classroom. In this scene, Roman catapults launch flaming projectiles at the barbarian hordes. As class begins, the instructor declares that the Navy goat is barricaded behind yonder castle and the students must assault the fortress using the catapult shown in Fig. 5. The purpose of the class is to use the work-energy equation to compute the standoff distance for firing the catapult. The students disassemble the catapult to weigh and measure its components. The mass moments of inertia are computed about the components' centroidal axes and then about the axes of rotation. Weights are hung from the rubber band to determine its force-displacement relationship. The work-energy equation is used to compute the velocity of the projectile (a golf ball) at release. Using the angle of release and velocity, the projectile motion equation provides the distance that the ball will travel. With heightened dramatic effect, the class is concluded by measuring off the computed distance and firing the ball at the Navy goat. Applying some lighter fluid and igniting the golf ball enhances the effect and is surprisingly safe. Hanus and Estes (2002) provide more complete details for both examples. There are many possibilities for simpler real-world examples that can build suspense without being the focus of the entire class:
- To illustrate the concept of zero-force members on a truss, the instructor hands a student a rope attached to a model truss (Fig. 6) and asks him to lean back, close his eyes, and pull on the rope while the instructor removes a pin from the truss. The instructor pulls the pin on a zero-force member, but the class is left wondering if the truss will collapse and send their fellow student crashing to the ground.
- A super soaker (humongous squirt gun) can be used to illustrate the Bernoulli equation in a Fluids course. Using two points on the super soaker, the velocity of water at the nozzle

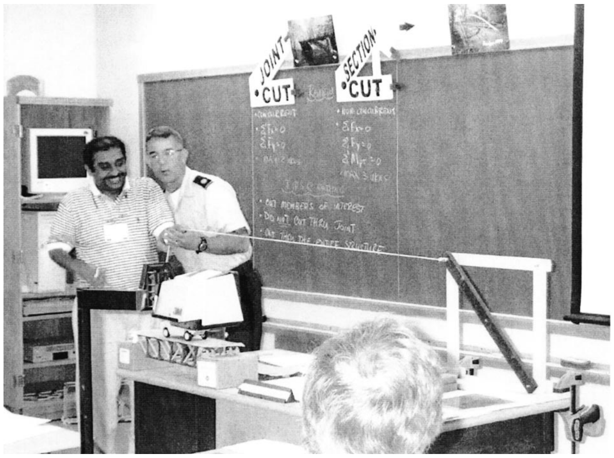

Fig. 6. A student is asked to close his eyes, lean back, and pull on the rope as the professor removes one of the pins to illustrate the concept of zero-force members.

of the toy can be computed before and after the system is pressurized. Pointing the soaker at the students and pulling the trigger after both calculations creates a degree of tension that will certainly keep them awake.

- To illustrate that the self-weight of a truss is negligible compared with the weight it can carry, a manila-folder truss weighing less than an ounce is shown to carry several pounds of textbooks. The successive loading of this paper truss creates suspense as students wonder how much it will carry before it collapses.
- In fact, any laboratory exercise where something is destroyed lends itself to suspense. The crushing of a concrete cylinder, the rupture of a tension specimen, the collapse of a wooden truss, or the fracture of a steel weld are violent reactions to large forces and will grab any student's attention. Creating suspense can be as simple as a prominently displayed brown paper bag that hides something that will later be used in class. Students will naturally wonder what is inside. One instructor occasionally places an sealed envelope containing a class exercise on each desk with a notice: "Secret envelope—do not open until directed." While this might simply be a means of saving time by distributing a handout in advance, it builds some drama, especially if the opening is accompanied by the *Mission Impossible* theme song or some other theatrical device.

Dressing differently can create either surprise or suspense. Wearing a costume on Halloween is an easy idea. An instructor might dress like Sir Isaac Newton and carry an apple to class when discussing the laws of motion. One instructor starts the first lesson on design with a particular ritual. Class starts with Vivaldi's *Four Seasons* playing at sufficient volume to attract everyone's attention. The instructor is silent, but successively adorns a vest and bow tie, lights a candle, smells a flower, and pours a glass of wine (apple juice, actually) while the students watch and wonder what is happening. The instructor assumes the role of the sophisticated, yet stodgy and snobbish, aristocrat and declares that analysis is the mind-numbing, number-crunching work of the lower classes. This lesson will elevate their station in life through the inherent beauty and infinite variety of design. While this does not make any of the students a better designer, it does set a tone and alerts the students that they are graduating to a different and more exciting topic, one that might be worthy of their attention.

Storytelling

All of the examples so far have included a physical demonstration or prop. A model that illustrates a theoretical principle can be so effective in the engineering classroom that it is the subject of next issue's Teaching Lessons Learned column, but it is not essential for dramatic effect. Much drama lies in the art of storytelling. A classroom lecture can achieve the same dramatic suspense as a best-selling novel if the presenter is excited about the plot, poses early questions to grab attention, drops clues along the way, creates interest and sympathy for the characters, develops some false leads, and saves the best for the exciting, satisfying, and conclusive finale. Civil engineering is filled with such stories that just need to be properly told. David McCulloch attained best-seller status with his separate chronicles of the Brooklyn Bridge (*The Great Bridge*) and the Panama Canal (*The Path Between the Seas*). Stephen Ambrose did the same with the transcontinental railroad (*Nothing Like It in the World*), and John Barry makes the compelling argument that the entire direction of the country changed because of a flood (*Rising Tide*). The construction of the Hoover Dam, the creation of the Eisenhower interstate highway system, the collapse of the Kansas City Hyatt Regency walkway, and the challenges in the Big Dig are all excellent examples in which lives and fortunes were at stake and the political, social, legal, and engineering ramifications were significant. Any of these stories can offer suspense if told in a compelling manner. Even a mundane topic such as metal fatigue can be exciting when preceded by vivid description of the deHavilland Comet and other aircraft in the early 1950s that mysteriously crashed into the ocean as a result of fatigue cracking. Engineering ethics case studies are particularly effective because they are stories that involve difficult human choices. The debates that ensue can generate strong emotions and interest. A well chosen, realistic case study with a controversial dilemma can provide suspense and drama, even for an instructor who lacks any ability to tell a good story.

Competitions

Students competing to outperform each other are a recipe for tension, heightened emotion, and drama. An examination review session in the format of *Jeopardy* or *Who Wants to Be a Millionaire* is an easy way to create suspense. Laboratory exercises where students compete to design the strongest beam, the best concrete mix, or the most efficient structure are excellent targets, especially when a formalized loading or testing of the final product is part of the exercise. Prizes, even those of low cost and dubious value, enhance student interest.

The West Point Bridge Designer software (Ressler 2004) provides an excellent venue for student competition at all levels. Students attempt to design the most cost-effective bridge and receive visual feedback as an unsuccessful design collapses before their eyes. The excitement and drama reach a feverish pitch in a timed competition, especially if the competing designs are shown on a common screen and the audience and competitors can see everyone's successive improvements. The software can be downloaded for free at http://bridgecontest.usma.edu/.

Another highly successful and effective competition is the K'nexercise (Ressler 1999; Estes et al. 2002), in which students role-play the key participants in the design-construction process. The K'nexercise rules attempt to provide the students with the same constraints and motivations experienced by the architectengineer (A-E), owner, project manager, material vendor, and contractor engaged in a real-world construction project. The A-E designs a structure to meet specific criteria using K'nex toys. Project managers review the designs. Contractor teams submit competitive bids for the project while vendors attempt to maximize their profit by selling materials to the contractors. The suspense is heightened by a timed construction event that determines the labor cost and a final load test to determine if the structure performs as intended. The students experience the same frustration and challenges as their real-life counterparts, and their behavior during the exercise often reflects this.

Conclusion

The list of suggestions offered in this article barely scratches the surface of virtually endless opportunities to bring suspense and surprise to the civil engineering classroom. If any reader has other examples, please share them via e-mail and I will add them to our growing collection. At a minimum, effective use of drama makes a classroom more exciting, sparks interest from the students, keeps them engaged, and causes them to think more than they otherwise might. When used best, drama can actually help a student understand and retain a key concept in a course. Drama requires more work, creativity, risk, and preparation to implement, but it makes the classroom experience more engaging and rewarding for the students and instructor alike.

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