AC 2008-1933: USING THE “WOW” FACTOR TO ACTIVELY ENGAGE ENGINEERING STUDENTS

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to Actively Engage Engineering Students

Abstract

It is a widely recognized trend today that students spend less and less time on their studies. Surveys of American college students document this reduction in study time and many educators assert that the average student currently spends far less time studying than is optimal for the assimilation of engineering concepts. This is especially true at a military academy, where highly structured time schedules scatters study time through out the day, and where students face all of the same hi-tech distractions as their civilian counterparts. To compete for time in this new study-scape, the study of engineering concepts must be re-cast into exercises that entice students with interesting and even entertaining results. In this paper we describe several projects that have been incorporated into the ME curriculum at the Virginia Military Institute (VMI) to keep students engaged in their studies and improve the acquisition of engineering concepts as well as design skills. In this paper the authors examine case-study projects used at VMI and, based on their experiences with these projects, conclude with a set of key characteristics that course projects should have to succeed as educational instruments.

Introduction

Engineering students today are part of a world in which the technology of “being connected” has entered every facet of their lives. Text messaging, the internet, wireless laptop computers, MySpace, YouTube, and video games are all forms of entertainment that may be accessed anywhere at any time, even during class lectures. Large amounts of time which might be used for study are now consumed in these virtual environments. In a survey of Penn State students it was shown that on average, students spent 4 hours a week on YouTube, a distraction which did not exist 10 years ago. The theme of the day seems to be, keep things short, provide immediate feedback, or your message will be ignored. Needless to say engineering educators have found it challenging to operate in this environment. Any material that involves lengthy derivation, or depends on several layers of theory or analysis, is subject to filtering by students. Assignments that require contemplation or self study to complete are often labeled as “unfair” by students who increasingly seek out rote solutions to engineering problems. While educators recommend any where from 25 to 35 hrs of study per week in engineering, surveys indicate that students spend only 10-15 hrs a week actually studying. At a military academy this problem is compounded since the structured environment that mixes academic, athletic and military training every day, results in the fracturing of usable time chunks for study during a cadet’s work day. During the evening, cadets often take part in extracurricular activities or spend time socializing so that their actual study time does not typically begin until 10 or 11 o’clock at night. In a survey of incoming freshmen, most students had only 2-3 hours spread out over the day in which to study, and even that is an optimistic estimate given that many students report that they may “take a study break to play a game or send email”. In many courses that engineers take, concepts are highly
abstract and require uninterrupted time to work through. Design projects can be even more challenging since design is an inherently non-linear process and requires coordinated effort distributed over time.

To engage students in their engineering studies, educators have put forth many new approaches:

- Delivering the concepts of engineering via new technologies
  - Podcasts
  - *YouTube* movies of engineering concepts / lectures
- Switching the format of teaching from “talk and chalk” to an active learning format
- Increasing the opportunities for undergraduate students to engage in undergraduate research

Each of these approaches seeks to freshen the educational experience for engineering students and pique their interest, and, in each case, many man hours are invested spent on the part of the instructor to implement the new strategy. While statisticians argue over the efficacy of these methods, it must be admitted that some of the improvements in education are due to transient effects such as the perception of the students towards new technology, or the initial personal investment of the instructors in a new program. Ultimately the best methods for educating engineers are the ones that show students the utility of the concepts presented in class for solving real world engineering problems. Independent study, undergraduate research, and student design competitions are excellent tools for making this connection and engaging students. Unfortunately, not all students can take part in these activities due to limitations on faculty time, or the requirement that students have some prerequisites to work on a particular project. The incorporation of active learning components within a class makes it possible to include all students. At the Virginia Military Institute, we have started the process of bringing active learning projects into the class room, and through trial and error have found that some exercises are effective training tools for the cadets, and that some exercises that seem equally well conceived and executed do not have the intended effect on the cadets. One concern that will be addressed in this paper is how to design the active learning content so that it does, in fact, appeal to students and enhance the learning process.

Engineering students at VMI are predominately male, action oriented and left to their own devices voluntarily spend large amounts of time playing video games or surfing the internet. As a group, they are turned on by military technology and are naturally drawn towards anything that flies, shoots or explodes, (WOW did you see that?). One of the ways in which we have been able to engage our students in active learning experiences is to exploit the “WOW” factor that so many of our students find engrossing. The basic notion is to incorporate materials into our courses that require a minimum of build time, and couple exciting outcomes with serious engineering analysis concepts. In all cases we have effectively used the “WOW” factor to engage students (sometimes passionately) in
subject matter that otherwise is not always considered all that interesting. The purpose of this paper is to present a suite of class projects that have been used at VMI as part of the mechanical engineering curriculum, and to distill from these projects a set of characteristics that seem to best promote a meaningful active learning process. While it is true that students at other universities might not find projects based on military applications as motivating as the cadets at VMI, the pedagogical characteristics identified here could easily be translated to other domains more appropriate to a civilian student body.

**Description of Projects**

In this section of the paper, a series of active learning projects that have been included in the mechanical engineering curriculum at the Virginia Military Institute are presented, starting with courses in the freshmen year and going on through courses in the senior year. Three of the projects described were designed explicitly to make use of the “WOW” factor, while the last project presented does not. In each case, the reactions of the students to the projects are reviewed, and it is shown, at least anecdotally, that the use of exercises that interest students in non-academic ways (i.e., the WOW factor) are much more effective for learning than other exercises.

a) **Freshmen Design Projects:** In the first semester of their freshmen year, cadets at the Virginia Military Institute take a solid modeling class where they are introduced to engineering graphics and solid modeling technology. After completing about 2/3 of the course the students understand the basics of the solid modeling and engineering drawing. For the last third of the course, students are assigned a course project that draws on the cadets modeling skills. In the past, students were given a reverse engineering project which required them to take measurements from an actual piece of machinery, and then generate all of the models, assemblies and associated drawings for the given mechanism. The project was a valuable experience for most cadets, as it forced them to extend the repertoire of skills taught in class, and in several cases, freshmen engineering students were able to obtain internships based on their project. After the dept. of mechanical engineering purchased a rapid prototyping machine 2 years ago, it was decided to change the nature of the course project to a design and fabrication project.

For the first year in which a design project was introduced to the course, a conscious effort was made to talk with the students about their outside interests when selecting the project. Many of the students had a deep interest in guns, and suggested that a good project would be to redesign some part of their school issued M-16 rifles. Clearly there was “WOW” factor associated with the design of a gun for the solid modeling students, so the project that was selected for the class made use of it. Specifically, the students were charged with creating a design for a toy hand gun, which they had to design then build on the rapid prototyping systems. Requirements for the project were as follows:
- The gun was to be powered by rubber bands only, and shoot ping pong balls
- The gun had to include a cocking feature and trigger for firing
- Any individual component of the gun was constrained to a size envelope of 6 x 6 x 10 in to satisfy space constraints in the rapid prototyper.
- Students were to create a complete drawing package for the design and then create all of the components to build the gun on the rapid prototyper.
- Design teams of up to 3 people were permitted in each group

The results were much better than expected. Design groups got to work immediately on their projects, researching cocking and firing mechanisms for firearms to adapt to their own designs. During class and afterwards, students could be seen at the whiteboards sketching and arguing about their designs in much the same way that real engineers do. Many of the designs were excellent and, upon seeing their rapid prototypes completed, the students seemed surprised at their own capabilities. A year after this first experience with a freshmen design project, many of the students involved still come back to talk about the project and to see if they could use the system again for other course projects. Certainly in this case, the use of the gun design as a project topic motivated the students to higher achievement than picking a topic for the design that was equally demanding, but of no interest to them, (e.g. a kitchen utensil, or a vice-grip).

b) **System Dynamics: Water Rocket Project.** Sophomore cadets in the Mechanical Engineering program take a course called “Introduction to System Dynamics” in which they learn to develop mathematical models for various physical systems. Particular topics include analysis of translational and rotational mechanical vibrations, analysis of passive electrical circuits, and the dynamical modeling of fluid and heat transfer processes. The purpose of the course is to introduce what a dynamic system is in the first place, and then go on to gain experience with some of the generic descriptors of a the response of a dynamic system, (e.g. transient and steady state response, time constants, natural frequencies). The course also serves to give an introduction, if somewhat abbreviated, to the various domains that mechanical engineers deal with such as vibrations, fluid dynamics and heat transfer. Emphasis is placed on the development of the governing equations and constraints that describe system response, not on solving differential equations. Students use MathCAD to determine the actual time responses of the systems considered, making it possible to concentrate more on generic performance characteristics and less on math. One of the problems with this course has been that students do not have a lot of background in any of the domain areas that they are modeling at this point, and as such, have trouble in understanding exactly what they are trying to accomplish. To the chagrin of instructors teaching the course, students were often heard to say “I got an A and still don’t know what a Dynamic System is”. To remedy this problem, physical examples were included into the course as exercises or demonstrations, in hopes that these would improve students interest levels and appreciation of the concepts covered in the course. Fluid systems were by far the most difficult to deal with since the material related
to fluids in the course was frankly not all that exciting. Pressure drops through piping networks, tank flow problems and fluid inductance simply do not lend themselves to interesting demonstration. As an alternative, it was decided to use a water rocket design competition as a means to motivate students to learn and apply the fluid modeling material covered in the course. On the first day of the fluid modeling part of the course, the students were led outside to the parade ground, and the instructor introduced them to the water rocket and launcher system. The system consists of a launching tube that pressurizes the air in an inverted 2 liter soda bottle that is partially filled with water. Upon releasing the bottle from the launcher, air pressure expels the water and creates the thrust that drives the rocket upwards. The students were mesmerized after launching a few of the water rockets, and as far as an educational tool is concerned, the launches created real motivation for understanding the fluid dynamics behind the flight of the rocket. After returning to the lecture hall, students identified:

- Compressed flows
- Incompressible flows
- Aerodynamic drag
- Flow resistance through a nozzle

as issues that would have to be understood in order to model the flight of the rocket. In subsequent lectures, the analytical details were filled in and continually related back to the rocket problem to maintain interest on the part of the students. Finally, the water rocket design competition project was released to the students. The purpose of the project was for students to use their mathematical modeling tools to design a rocket that would fly the highest, based on a 2 liter soda bottle and an 80 psi firing pressure. The specific variable that students needed to manipulate in their analyses was the volume of water used to propel the rocket.

Guidelines for the project were as follows:

- The project could be done in groups of up to 3 students
- Each design team was required to build a rocket using a standard 2-litre soda bottle. It was their job to customize the bottle using fins, nose cones and weights to improve the flight characteristics of the bottle.
- The object of the competition was to build a water rocket that would, when pressurized to 80 psi, fly the highest.
- The primary variable that students had to manipulate for their designs was the volume of water used to fill each rocket before pressurization and firing.

Dynamic modeling for the project was discussed interactively in class and through the course of their work on the project students got to delve more deeply
into issues like determination of drag coefficients and stability of projectiles. As far as results are concerned, the general trend was for students’ height estimates to overshoot the actual height to which the rockets flew. Although this would seem to suggest that the project was not a good one, in practice, the disparity between model predictions and the experiment was something that engineers face all the time and offered valuable lessons. Students were forced to figure out where their assumptions broke down and why that limited the predictive capabilities of their models. For example, most of the rockets went into a flat spin at some point in the flight and stopped the rocket from rising higher. Students that added weight into the nose of the rocket improved the stability of the rocket and achieved results much closer to their model predictions. Despite the limitations of the students’ models to predict firing heights with complete accuracy, the models were able to capture the trend between the filling volume for the rockets and the resulting height achieved by the rocket. Again, this served as a valuable lesson for students, demonstrating that engineering concepts can be used to understand the general behavior of a system, even in the case where it is not practical to model all of the features of that system.

c) **System Dynamics: Potato Gun Competition.** The water rocket described in the last section was very successful as a teaching tool and as a means to excite students about their studies. The next time that the system dynamics course was taught in the spring of 2007, it was decided that to keep things fresh and maintain student curiosity a different project should be brought into the course to cover fluid modeling concepts. The “WOW” factor was brought into play again, this time to have students analyze a pneumatic powered potato gun. The goal of this project was for the students to develop a model of the trajectory of a potato being fired from the gun, and then use this model to determine the charging pressure and gun angle that would be required to hit a target 250 feet away from the launch point. Concepts that the modeling project used included:

- Adiabatic expansion of a gas
- Aerodynamic drag
- Sliding friction
- Valve resistance

This modeling project was considerably simpler than modeling of the water rocket, however still had significant challenges. For example, what is the best way to model the expansion of the gas in the gun? How should the drag on a potato be accounted for? How should the sliding friction of the potato in the cannon barrel be accounted for? In some cases, theoretical approximations to the actual physics had to be made, like using adiabatic expansion to describe the gas even though this assumption is only completely accurate under equilibrium conditions. In other cases, such as determining the sliding resistance force on the potato, the best means was direct experimentation. Results of the modeling effort actually proved to be pretty accurate even in spite of the simplifying assumptions. In many cases students were able to reach within 25 feet of the target, and two teams were able
to hit the target using the firing parameters determined with their models. In comparison with the water rocket project, the potato cannon was actually a more satisfying teaching tool since the accuracy of the results really showed the utility of going through all of the analytical modeling. One indicator of the success of this project was that, in the subsequent fall semesters, several of the students who had been in the system dynamics course developed their own cannon designs for shooting tee-shirts into the upper bleachers during VMI home football games.

d) **Mechanical Design: Analysis of a Trash Compactor.** For this last case, an active learning exercise that was developed for the senior level mechanical design course is presented as an example of a project that was decidedly lacking in the “WOW” department. The exercise consisted of the mechanical dissection of a trash compacting machine, with the deliverable being that students analyze the power train and determine the compression force of the machine. The machine itself was powered by an electrical motor, and included belt drives and chain drives for speed reduction and a set of lead screws for the final conversion of rotary power to linear translation. As an active learning exercise, the trash compactor seemed to be an excellent candidate with all components easy to access and measure, and many design details out and available for the eye to see. Surprisingly, students were not receptive to this project and some were actually annoyed that they had to actually go into the lab and measure something versus doing a problem out of the book. Many of the students did not start the project until the last minute, and were unsure of what to do with the measurements that they took. In retrospect, it became apparent that the project failed to have the intended effect because it did not hold the students’ attention--- It had no WOW power. From this example it can be seen that even projects that seem conceptually sound are not going to motivate the students unless they feature some kind of effect that is interesting to the students. For the trash compactor project some simple changes that could have totally changed students perceptions from drudgery to flat out entertainment. For example allowing the students to modify the drive train, until the trash compactor was able to crush an unopened soda can would’ve provided a much more dynamic demonstration of their learning. The bottom line is that many projects that fall short of expectations could be made into more effective teaching tools if they included an effect that is interesting in and of itself, independent of the engineering discipline.

**Discussions**

Based on our experiences at the Virginia Military Institute, the most successful active learning projects should include the following features:

- **Teamwork:** students benefit from working on a team/ strong students get to lead and teach, week students get to ask questions and learn in a an environment that’s less threatening
• The project must have an outcome that is exciting to the audience for which it is intended. There may be many experiments/projects that would show students a concept equally well, however, if the students aren’t drawn to the outcome, they won’t enjoy spending time on the project.

• The project must be real: numerical simulations without physical demonstration might as well be a DreamWorks production to our students. This generation has grown up with computer animation, photo shop and gaming technology that simulates Armageddon with sinister realism. It is only natural to expect that they would view numerical simulations as a kind of fairy tale and put more faith in experiments that can be demonstrated on real equipment.

• The project should not include too many independent variables. Students should be able to manipulate a few variables and get a large observable effect. Projects where there are uncontrolled variables with large effects obfuscate the concepts that the exercise is trying to show. Students inevitably begin to doubt that the “real world” has anything to do with engineering models.

• Projects should be competitive. If possible, the project should have a competitive component to it. In the process of getting to a “winning result”, students will investigate more nuances of the engineering behind a project than if there is no competitive component.

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