AC 2012-3465: ALL OF ME IN ONE SHORT SEMESTER

Dr. Benson H. Tongue, University of California, Berkeley

Benson H. Tongue has been a professor for many years at UC, Berkeley.

All of ME in One Short Semester

INTRODUCTION

Changes in student preparation are causing the many ME departments, the author's among them, to rethink their approach to undergraduate education. In a nutshell, the words "recruitment" and "retention" have now made places for themselves in the undergraduate program's lexicon. Not so long ago, one expected students to declare their major during their high school application phase, marking them as future mechanical engineers before they ever stepped foot on campus. Although this route certainly is still used, the last few years have seen a marked increase in the number of undeclared students entering their universities and colleges. Once there, they are able, with varying levels of difficulty across schools, to join whichever engineering department seems most inviting.

The reasons for the reduction in the numbers of students who know from a young age that they are ME bound are not too difficult to discern. The opportunities for students to experience mechanical engineering in their pre-college years are far more restricted than in prior times and there is no sign that this trend will be reversing any time soon.

Consider the traditional "hands on" means through which many future engineers first realized their calling - working on their cars. Turning a wrench on a 1964 Mustang sparked an interest in countless students, letting them realize that they enjoyed working on, and thinking about, *mechanical* systems, something that then aimed them naturally toward mechanical engineering.

As part of the irresistible urge toward efficiency and performance, modern vehicles have changed in fundamental ways, ways that preclude any deep involvement for the novice. No longer can a student remove a carburetor and start to understand some basic fluid dynamics. Modern cars have eliminated them and replaced them with electronic fuel injection. All the engine controls, once accessible to a screwdriver, are now overseen by several on-board processors, each of which is tucked away in a neatly sealed box. Even such a simple thing as wanting to remove a door panel to try and unstick a window regulator is now fraught with peril from potentially explosive air bags.

Ironically, many of these changes are due in large part to the efforts of mechanical engineers themselves, who have unknowingly affected the lives of those who might have the aptitude to follow in their footsteps by reducing the opportunities for these young people to discover their own affinities for engineering. And these changes are not unique to the automobile, of course.

As the opportunities for involvement in mechanical systems has diminished, so therefore has the individual student's ability to know whether he or she would prefer mechanical engineering, civil, electrical, and so on. They know from their high school classes that they are skilled in math and science but that is often the extent of their awareness. Their high school counselors will look at their math and science scores and suggest engineering but the students will not have much more of a conception of what engineering really *is* than will the average person on the street. In fact, many students in high school will decide, based on their

interest in their physics classes, that they would like to pursue physics, not realizing that in today's world high school physics classes most closely resembles mechanical engineering practice, not modern theoretical physics.

Many students respond in a reasonable way to this uncertainty - by seeking admission in the undeclared category and hoping to decide on their ultimate path once at the university. But, of course, most of their first courses will consist of required background material in science and math - not engineering. And the danger here is that students may opt out of the engineering track before they have really had a chance to experience it.

Thus our departments face a two-fold challenge with regard to lower division students. The first is that of retention ([1], [2]), motivating newly admitted students to remain in mechanical engineering even though they most likely are doing rather little engineering in the bulk of their courses. And the second is to steer interested students into mechanical engineering instead of watching them move into a different branch of engineering or out of engineering entirely. As a way of addressing these issues in a modest way, the author has continuously offered a first-year course over the last decade or so that aims to attract, retain, and educate incoming students. The name of the course is ME 24, Art and Science on Wheels. Its enrollment is limited to 12 students, for reasons that will be delineated in the discussion to come.

COURSE CONTENT

When the author began, it was with the presumption that the incoming students understood a fair bit more than they actually did. Relatively quickly, though, came the realization of just how little these students knew of engineering. With this understanding, the course took shape as a place in which to learn widely about the field and, in addition, a bit more deeply about a particular aspect of engineering. As such, it has become one of the few avenues that allows a student who is as yet undeclared to dip a tentative toe into the mechanical engineering waters and decide whether such a major might be right for him or her. If the answer is yes, they can start the process of transferring. And, in the case of someone that has already declared their intent to major in mechanical engineering, the class provides a way for them to reassure themselves that their decision to major in the field was a good one and to make contact with a professor in a relaxed atmosphere. It allows them to weather the storms of chemistry, physics and mathematics, knowing what lies ahead.

The task as the author saw it was to:

- Offer a class that appeals to students who might potentially be interested in pursuing mechanical engineering as a profession.
- Structure the class so that the students themselves are responsible for some of their own education, a key element of effective learning [3].
- Highlight a representative array of mechanical engineering disciples so that students can better understand the breadth of the field.

- Increase the students' comfort level and abilities with respect to report generation and public speaking.
- Expose the students to a mild form of research.

In order to develop a cohesive framework for the class, the author zeroed in on two particular paradigms of mechanical engineering - the automobile and the bicycle. As the following list reveals, each facet of the field finds expression within some aspect of an automobile.

1. Fluid Mechanics - Low speed aerodynamics, vehicle resistance to wind gusts, highway vehicle dynamics in the large
2. Dynamics - Vehicle oversteer/understeer, vibration from road/engine, transient lateral dynamics
3. Combustion - Basic process of the Otto cycle, variants such as Wankel engine, hydrogen combustion
4. Controls - Stability control, HVAC automatic climate control, engine management, intelligent cruise control, hybrid operational control
5. Design - Interior and exterior visual design, ergonomic design, structural design.
6. Manufacturing - Robotic assembly, just-in-time inventory scheduling, shared platforms
7. Solid Mechanics - Computational crash testing, tire modeling and design
8. Materials - Lightweight new construction approaches - carbon fiber, aluminum, steel, plastics, replaceable plastic body panels, soft touch materials

Although not as comprehensive an example as the automobile, the bicycle embodies a wide range of engineering disciplines as well and has the advantage of being extremely accessible to college students. Most students own a bicycle and essentially all have had one at some time in their lives. The fact that they are powered by the rider is of significance as it allows me to tie in the power generation aspects discussed in the class to the rider, i.e. view the body as an engine and draw parallels between the torque/hp characteristics of a car with the torque/hp characteristics of a rider.

Some areas of engineering that are exhibited by a bicycle include

1. Aerodynamics - Drafting in bicycle pelotons, skin suits, aero wheels.
2. Materials - Frame materials - steel, aluminum, carbon fiber, titanium
3. Dynamics - Cornering, yaw instability in mountain biking, shock absorption in shock struts
4. Design - Different design solutions for mountain biking, road biking, downhill biking

5. Design - Kinematic/force considerations of different brake systems.

The foregoing gives just a few of the areas open to discussion. Clearly there exists no lack of potential topics on which to research and speak. Each semester a slightly different mix of topics will, in fact, be touched upon, depending on student and instructor interests.

COURSE STRUCTURE

Now that the basic "what" of the course has been delineated we need to examine the "how." How are these pieces integrated over a semester to motivate and hopefully attract students?

What needs to be created at the start of the class is a thread of continuity that lets the students realize there is a big picture as well as each weekly "little picture." The sequence of class discussion topics should reflect this larger framework in such a way that the students can see how each week's work has more completely limned the overall theme of the class - in this case automotive-bicycle technology as a microcosm of mechanical engineering in general.

Day one

The first day of the class is used to introduce the philosophy and goals of the course. Being a freshman class, with students unaccustomed to university rigor, the author has found it important to indicate clearly what will be expecting of the students over the semester. If any of them were thinking that the course would be no work and an easy pass, they are hopefully disabused of this notion by the end of the hour. This is also when a list of research topics is distributed, from which the students can choose which areas most appeal to them. They are instructed read it, think about it a bit, and then to email their preferences during the next few days. This gives them their first chance to get involved with their own education and by giving them a choice of topics they can target the areas (usually two or three) that they feel would be most interesting to them. If they have no particular preference, as is sometimes the case, then they'll be assigned a topic. Conversely, if five people all want to discuss turbocharging technology, the author will have to step in and choose the lucky applicant.

Next up is a discussion of how the topic sequence will create a coherent picture of mechanical engineering via our automotive and bicycle framework. The early talks will deal with basic elements, such as the Otto cycles and later ones will move further afield, considering, for example, active control technology applied to the entire vehicle's dynamic response. Finally, they are told that attendance (save in the case of pre-approved absences) is an absolute requirement. In most classes the student can pass the tests, not attend the classes, and still pass. That is decidedly not the case here.

Day two

The second class meeting is a crucial one because it is the avenue through which the author indicates how a "good" talk is given. This first talk usually presents a history of the bicycle and make mention of the elements that are mirrored in cars. The goal, beyond presenting

a hopefully engaging talk, is to let the students see how to create slides with the correct amount of material on them, i.e. very little in the way of verbiage and a good deal of graphic imagery that supports the particular points being made in the talk.

Experience has shown that students often have amazingly little experience in giving any sort of effective presentation. They overpower their slides with too many words and too few graphics. They spend their time reading to their audience and do not realize that, with the text already on the screen, they could simply keep quiet and let their audience read.

After this introductory talk has concluded, the author leads a short discussion of how the talk was structured - what material was disseminated and how. This gives the students the explicit guidance they need to create their own presentation. The students are reminded at this point that, in addition to the presentation itself, they are responsible for a paper, complete with references. When the author first began having students prepare presentations as part of the class, not requirement was given to them beyond preparing and giving the talk itself. Consequently, the level of preparation and research was, to say the least, variable. By requiring a multi-page report, complete with references, they are put on notice that the talk has to be more than simply a cut-and-paste from a webpage.

The talks are limited to 20 minutes or so, leaving room for discussion afterward. This forces them to think critically about what is relevant and what is not. They are informed that several dry runs in the comfort of their own dorm rooms is considered mandatory. Interruptions during the talk are encouraged, both to acclimate the students to what a real-world research presentation may someday entail and also to follow up on items of interest while they are fresh in the questioner's mind.

At the end of the talk we will have the usual question period. If the students do not have any questions of their own the author will either probe deeper into the subject of that week's presentation or use the time to discuss some further detail from a prior talk or related material that would inform the day's talk.

The week after a student gives his presentation they will receive a short written critique, going over both the content of the talk and the quality of the presentation itself. This critique is kept upbeat but if there are points that truly need attention they will be pointed out.

EFFECTIVENESS AND EVALUATION

It is appropriate at this juncture to ask the question "Does it work?" And the answer is that, on a multiplicity of fronts, it does. Near the end of the semester the students are asked by the administration to evaluate their courses and the course overall ranking has consistently fluctuated between 6.5 and 6.9 on a 7.0 scale. Clearly, the students are highly satisfied with the experience. Written comments delineate more precisely why they are feeling positive and show that the course's predetermined goals are, in fact, being met. High on the list of positives are comments such as "lets me see what Mechanical Engineering is all about" and "So THIS is what all the math is for." Additional areas routinely highlighted by many are the opportunities to do research on their own as well as to construct and present a technical talk.

Beyond that, individual students in the undeclared group are getting enough of a positive feeling so as to induce them to join the mechanical engineering department as well. They took the course to get a sense of what the field was all about and left sufficiently motivated to join up. The author has been giving the class long enough now (over a decade) that several generations of freshman have moved through the ranks to become graduating seniors and often these seniors will tell me that it was this particular class that convinced them early on that a degree in Mechanical Engineering was worth pursuing. It showed them what they would eventually be able to do and made it easier to soldier through the required lower-division math and science requirements.

CONCLUSIONS

The structure and content of a course that effectively attracts and retains students has been presented. Nothing about the course relies on particular resources of the author's home institution and it could relatively easily be fielded at other schools. Student interest in the class is high and to date no student has ever failed to pass it.

For all its positives, though, there is one drawback and that is one of size. Vital to the course structure is the opportunity for students to undertake and present research of their own, one topic every class session. Obviously this places a hard upper bound on the number of students who can be accommodated (one student presentation per class). The author's view is that some is better than none and therefore, in spite of its necessary enrollment limits, it is well worth continuing.

References

[1] Demel, J.T., et.al., *Bringing About Marked Increases in Freshman Engineering Retention*, Proceedings, 2002 ASEE Annual Conference and Exposition, Montréal, Québec.

[2] Rojas-Oviedo, Ruben and Qian, X.C., *Improving Retention of Undergraduate Students in Engineering Through Freshman Courses*, Proceedings, 2002 ASEE Annual Conference and Exposition, Montréal, Québec.

[3] Kigley, K.A. and Marianno, C.M., *Making Engineering Education Fun*, Journal of Engineering Education, pp. 107, 2001.