EDITORIAL

And More Again on the State of Engineering Education, Part 1 of 3 – Dirty Hands

***Peter Avitabile**, Contributing Editor*

As a general rule I don't like writing editorials, but I often get asked to do so. There I was on vacation, during the holidays, and I decided to bring along some magazines to catch up on my reading. (I just don't have time to read on a routine basis anymore.) I started with one of those 'other' testing-type magazines and among the first pages I found one of these "old timers" rattling on with tips from the seasoned 'dean' of shock and vibration. Of course, there have been other articles written in that same magazine that basically look at the new engineer as an incompetent youngster with a "piece of paper" but no practical knowledge to go along with it. The only ones who know what to do are the seasoned technicians who have all the experience and answers. (I vowed two years ago to write an article to counter those statements but refrained mainly out of lack of time to do so.) Anyway . . .

So I picked up a copy of *S&V* and read a well written editorial related to the state of engineering education, the accreditation process, and the constraints we have placed on ourselves by the accreditation process. The reference to Strether Smith's editorial contained in the first paragraph sent me scrambling to the web to find this July 2004 Editorial. (Thank God we have the web and almost instantaneous access to most everything we need – thanks for putting that webpage up, Jack! – otherwise I would have been wondering on the trip home what was written in that editorial and maybe never getting to write anything due to time constraints. Instead, there I was on a Saturday night, up in the mountains, sipping my drink, watching football playoffs and writing this editorial.)

"Lay on McDuff, and don't turn back, for if he do, he may regret." (Or at least I think that's the way it goes . . .) Strether Smith's editorial requested feedback. In this editorial, I will try to give a quick glimpse of the "dirty hands" engineering program that we proudly put on here at UMASS Lowell, but I would rather refer to it as "hands-on" engineering as a better description. (Parts 2 and 3 will further elaborate on some of my thoughts on this very important item.)

The four year program in mechanical engineering is heavily loaded with a practical, hands-on curriculum, with significant analytical projects involving real hardware and requiring significant experimentation in the process. The curriculum also puts a heavy emphasis on project work, involving teams, with formal reports written and technical presentations provided. While I cannot elaborate on all aspects of the program, I will expound on several topics that highlight the solid mechanics, design, vibration/dynamics and laboratory experience of our students. I will specifically speak of the Mechanical Design course (22.321), the Mechanical Laboratory sequence (22.302/403), and the Dynamic Systems course (22.451) which I feel will amply show that our students get a *real* look at *real* engineering from all aspects.

In the Mechanical Design course, students have typical lectures that are complemented with a semester-long design project. The task is to design a simple four bar linkage with specific requirements for location and dwell points with the linkage driven by a constant speed motor. Each student is given design parameters based on social security numbers which makes every design very unique – and very difficult to copy answers from other students. The students use a variety of tools to design the linkage including hand calculations and simple drafting tools to firmly instill fundamental concepts in the students' minds. These are complemented with CAD and other advanced tools to enable efficient design development. Once individual students have completed this phase of the task, groups of three or four students are formed for the balance of the work. The groups then perform displacement, velocity, acceleration and force analyses on the linkage, and develop a detailed design that is complete with all proper engineering drawings to be issued to the shop for manufacture of the linkage. The only catch is that the students must do all the machining and fabrication themselves to complete the design, providing an invaluable experience that goes beyond the paper-based analysis and design. The students then proceed to a competition where all the designs are subjected to performance testing. In the process of this semester long project, the students submit interim reports every two weeks on the various stages of their design. At the completion of the project, a full report is issued identifying all aspects of their design. The students enjoy this project since they are actively involved in understanding the theory in progress – and their hands really do get very dirty. (Some linkage designs from 2001 can be seen at: http://m-5.eng.uml.edu/22.321/Fall2001/final_linkage_demonstrations.htm)

The Mechanical Laboratory sequence is another very hands-on oriented course. In many universities, laboratories are conducted by the instructor or teaching assistant with the students as the audience. However, at UMASS Lowell, the students are very active participants in every laboratory. The laboratory courses are taught in a two semester sequence. The first semester concentrates mainly on basic measurement tools (oscilloscopes, multimeters, digital data acquisition, etc.), measuring devices (flow meters, manometers, pressure transducers/gages, pitot tubes, strain gages, thermocouples, accelerometers, LVDTs, etc.) and methods for data collection/reduction (regression analysis, curvefitting, numerical processing). The first semester has many different labs that, in general, are intended to get the students exposed to the overall mechanical measurement world. However, a few labs are intended to force the students to work through several difficult issues. One particular lab forces the students to struggle with real world measurements of displacement and acceleration that are contaminated with drift, bias, offset and quantization errors which plague numerical processing (differentiation/integration) of the data. The second semester is split into two halves. The first half continues the more structured lab environment but introduces more complicated labs and concepts including Fourier domain processing techniques with FFT analyzers. The second half of the semester concentrates on the student design and development of a measurement system given only vague specification of the overall measurement requirements or problem to be addressed. Notice that I said "design and development of a measurement system" and not "usage of these devices to make a measurement." The student must formulate and design a measurement system to achieve the required goals. In order to achieve this, the students must draw on all of their educational knowledge, not just their lab experience. As an example, in the Fall 2004 semester projects consisted of:

1. Designing a strain gage pressure transducer for the closure head of a pump system with filtering for pulse attenuation.
2. Designing a filter system (high pass, low pass, band pass) for the signal cleansing of a noisy LVDT and accelerometer signals for structural response.
3. Design of a measuring system of the dynamic tip response of a cantilever beam using three noncolocated measuring devices (from a choice of LVDT, accelerometer, eddy current probe or laser) and a digital data acquisition system.

This five week project culminates in a

full formal report and presentation. In general, the students have enjoyed the lab experience since they are taxed to integrate material from many other courses to understand the problems at hand and to effectively make sound judgments and design decisions. This laboratory sequence is far from mere service to illustrate simple concepts presented in other engineering courses. The laboratory sequence forces the students to take ownership of material to solve the problems they face.

The Dynamic Systems course follows with a similar approach. The students have traditional lectures, tests and homework, but the course is supplemented with three projects that integrate material from both analytical and experimental perspectives. The students are required to develop a traditional differential equation solution along with a Laplace solution to a second order mechanical system, which are supplemented with solutions using MATLAB® and Simulink®. The second order system is defined by mass, damping and stiffness values again derived from their social security numbers. Initial conditions are defined by their birthday and birth month, which ensures that every student has a unique problem to solve. This first project is intended to refresh and hone their required mathematical skills. The second project involves the measurement of a simple single-degree-of-freedom, mass-spring-dashpot system in the lab using appropriate measuring devices. The students are then required to formulate an analytical model from the measured parameters. However, some of the physical parameters are not clearly defined and the students must decide how best to determine the physical properties. There are several different approaches to address these parameters and many different ones are possible. The students work in teams and then submit their formal report. But, rather than having the instructor review the reports, they are anonymously redistributed to other groups for a peer review. This critical step allows the students to review alternate approaches taken by other groups as well as review the reports for clarity and completeness. The process proves to be very enlightening for all the students. The final project changes year by year but generally has some additional aspects of filtering or first order system time/frequency response. As in the other application-oriented courses, the students enjoy the actual hands-on aspect of the Dynamic Systems course because it helps to clearly identify the relationship between theory and a real system.

In Part 1 of this editorial, I hope that I have presented a very good glimpse of the hands-on approach to teaching engineering here at UMASS Lowell. I believe that engineers learn by doing – not seeing or being told – and a laboratory is the best place to do just that. We strive to educate our students using the very best techniques. Here at UMASS Lowell, that approach has included traditional classroom lectures with a strong, application oriented, hands-on approach to solving real engineering problems. I believe that we graduate very good students who have acquired a very strong analytical capability coupled with good practical design and analysis knowledge and with a very comfortable familiarity with experimentation. There are some parts of our program that are truly unique but I would hope that many schools have similar approaches to educating their students.

So in response to Strether Smith's request as to how other schools address education, I hope I have conveyed one viable approach (which we have been doing here at UMASS Lowell for the past 15 years or so). In the next two parts of this editorial, I will expound on some other issues that need to be faced. S&V

The author can be contacted at: peter_avitabile@uml.edu. Parts 2 and 3 will be presented in the June and July issues of *S&V*.