

Importance of the “Edges” of Science

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Before beginning my talk, I should warn the audience of all the things I am not ! I am not the greatest teacher, nor the greatest research worker, nor the best expert in any of several fields of endeavor. I think I know how to motivate senior Electrical, mechanical, or civil engineers. They all are recognizing the necessity for dollars, and the employment that produces them. I know where some of those are, thus avarice applies in the College of Engineering at UTSA.

My own background is quite varied. My doctoral degrees are in basic medical sciences, but as a result of early contact with Neurophysiology and the instrumentation necessary for following optical responses in Limulus, or nerve action potentials in rat sciatic nerve, or microelectrode responses in rat brain cortex, I was somewhat prepared for study of the equipment required for electron spin resonance spectrometry, Nuclear magnetic resonance spectrometry, the initial precepts of magnetic resonance imaging all of which required a great deal of home study and consultation with local instructors. As a result of that preparation, the USAF School of Aerospace Medicine thought I should work on Biological responses to RF and microwave radiation. The latter activity required a great deal of study of electromagnetic interactions and I was very grateful for tutelage from Frank Greene and Howard Bussey then at National Technical Institute, Boulder, Colorado. Later, Bill Stavinoha, Andy Deam and I collaborated on the development of microwave brain inactivators which led to a quantum jump in the knowledge of Acetylcholine concentration and distribution in a variety of animal brains. After using some of this knowledge in development of RF tumor hyperthermia equipment at M.D. Anderson, UT Cancer institute, I began teaching Electromagnetics and basic electronics at the University of Texas at San Antonio.

Perhaps because of this varied background, I have become convinced that instructors in engineering and basic sciences often forget the kind of environment their students are going to find during their working life. While focusing narrowly on individual subjects, broader perspectives and the probability of change don't seem to have a comfortable place in most curricula at the present time. I offer some examples of the consequences of not looking over the “Edge” of a discipline to see where it is being applied.

About 30 years ago, the faculty of the Harvard University Medical School decided that courses such as Biochemistry, Physiology, Microbiology could be taught as “Virtual “ courses via computer, where even the examinations were presented as a computer exercise. It was thought that such courses would allow more student time for study and that there would be great savings in laboratory space and instructor time. Three years ago, it became pretty obvious that clinical proficiency was declining and a new era of “Hands-on” experience was re-introduced. There is greater use of student groups, more instructor guidance, and associated very valuable computer assistance programs as well as a series of lab exercises. So far, student performance seems to have improved.

About 45 years ago I was assigned as a fresh-faced ensign to the Navy School of Aerospace Medicine in Pensacola Florida and came into contact with Captain Perry Barr's group who were studying the effects of high “G” maneuvers on pilot's heart action. Data from EKG and blood pressure was obtained in then new jet aircraft and, via some pretty remarkable electronics, telemetered to a “Flying Laboratory” in a larger transport craft. When presented to clinicians, the data could not be interpreted at first. The design engineers had attempted to insure the widest frequency band possible in obtaining and transmitting the data, but this was not the type of data clinicians could interpret. The methods used for clinical interpretation had been compared with cardiac changes found at autopsy over a period of 30 years, so they were accustomed to data obtained by use of low frequency galvanometers with a frequency range of 0.1 Hz

to 100 Hz. When the telemetered data was passed through appropriate filters, the data could be clinically interpreted and the effects of acceleration on pulmonary and arterial vasculature began to emerge.

Later, we found extreme right heart effects in experimental animals at USNADC Johnsville. This, and many other kinds of data led to NASA's current designs for the equipment used in space and during reentry exercises.

These two homely historical events illustrate the importance of some teaching techniques, and the fact that no practitioner of any of the various fields of Science can become so specialized that he or she is ignorant of adjacent fields of study. In the case of basic medical sciences teaching, it became necessary for students to know some of the basic precepts of spectroscopy and electronics in order to properly interpret the laboratory results presented to them. With the increasing sophistication of data analysis and computer interfacing, it becomes more and more necessary for the clinical worker to detect numerical errors, technique artifacts, and transmission errors. Modern advances in vector cardiography, chest impedance measurements either as a diagnostic technique or as a post-surgical monitoring technique require strict attention to electrode characteristics, transmission characteristics, and electronic misbehaviour in order to properly interpret the data applied to physiologic measurements. The engineer, nurse, clinician, and technician all have to understand the variables involved. The laboratory results are obtained in the real world with real consequences.

So also the engineer, who must understand the applications to which his design is to be applied. At UTSA every graduating senior must complete a capstone design project. This project may include information from every subject to which the student has been exposed, and some information which must be searched for in publications, the web, or private conversations with the faculty. For electrical engineers, the requirement is for a project which is saleable, includes at least one microprocessor, and holds forth the possibility of forming a small business enterprise. The course is divided into 2 parts: a 1-hour course that includes business structures, ethical and professional practices, completion of a small business administration loan application with financial disclosure, and several presentations of project ideas, culminating in a full scale project proposal. Some care has to be exercised to include University rules concerning intellectual property rights, particularly because the students are encouraged to seek out sponsors who might donate parts or cash for specific projects. There can be no partnership or formal arrangement other than as a donor without implying partnership with the university requiring legal help.

Design 2 gets down to the nitty-gritty of circuits involved, types of equipment, power requirement, exact calculation of frequency response, motor or inductor controllers, interface with controller and computer. Or, in general, the problems encountered when a real product is to result. Nearly every upper division class, including the laboratories, has similar, but smaller scale projects so that the students know what's coming, but still usually encounter difficulties with project completion by the end of the semester. At times, it is necessary to assign a grade of incomplete so the student can finish the project in a following semester. Sometimes this delays graduation.

The difficulties students get into during this "Capstone" experience are traumatic to students and faculty alike. One common difficulty surrounds the use of a computer for programming a microprocessor-often the pulse amplitude coming from the computer is unknown, despite courses in microprocessor programming, but always with the computer interfaced to an evaluation board that controls power, pulse height, memory, and may do translation from C to assembly language. Obviously, any use of a microprocessor requires a similar control board and the students have never examined their own evaluation board. They have never examined the "Edges" between their "C" programmed assembly language and the actual events in their microprocessor, though some of that had been explored in lecture. Their instruction had been so narrowly focused that broader circuit implications had been left out. Such events are cause for some thought since one of the goals many of the students wish to attain is a job fabricating microprocessors and computers.

Another sort of difficulty results from instructor inattention in this type of course. In a recent "HEDS-UP"

Mars habitat senior design project, a robot was to be constructed which could automatically tend to growing plants before humans were scheduled to arrive. A moving 3-tier table was constructed successfully, but the microprocessor was very limited and continual problems were associated with transients introduced from motors which effectively re-programmed the microprocessor. That particular problem was solved by use of independent power supplies and fiberoptic interconnects, but no one paid attention to monitoring battery voltage so success was short-lived. A later group then tried to make the robot avoid objects, but no one paid attention to the fact that sound transmission in the Martian atmosphere was very likely not going to allow ultrasonic transducers as a sensing element, so the project was somewhat successful, but not useful. The "Edges" weren't carefully examined. The development of the recent Mars lander by NASA-JPL revealed, by testing, deficiencies in almost every subsystem that had been used in previous attempts at landing on Mars. In spite of great attention to detail, control system boards had to be replaced literally on the way to the launching pad. If testing had not revealed the defect, another failure would have ensued. At present, I don't know the cause of the board failures, but I would bet on the same problem that has assailed so many of our senior design projects-line transients that caused program alteration or chip failure. Very hard to design around this kind of problem unless scrupulous attention is paid to transmission characteristics of all system connectors.

One can learn a lot about students and graduate students by teaching in laboratory oriented courses. Many EE faculty avoid such teaching like the plague. They can't be blamed for such avoidance at UTSA since a 3 hour lab meeting twice a week plus one hour for lecture is worth one teaching credit. Another credit goes to a graduate student who is supposed to run the actual laboratory. In practice, most graduate students have never seen equipment such as swept frequency generators, controlled power supplies, spectrum analyzers, 2 types of digital oscilloscopes or Labview programming for control of external circuits by means of virtual instruments. They have been so narrowly trained as to be virtually useless in real applications.

Because of this, the instructor is in the lab 6 hours/week /section, plus 1 hour lecturing, plus extra time training graduate students for 1 teaching credit hour. This past semester I had 3 sections, Since they all met together for the 1 hour lecture, I taught 19 + contact hours for 1 teaching credit. One must be willing to devote a lot of time for nothing and also be very good at mental hopscotch to teach such a course. This particular lab course requires the student to design and build 2-sided photo-etched circuit boards for several multi-unit circuits where the total impedance of each microstrip is calculated and measured. It becomes apparent immediately that most of the students have no knowledge of simple power tools such as a drill press, and have almost no conception of precision or accuracy in measurement. These are seniors. They routinely expect to be employed as computer designers or chip designers where, they think, such knowledge is unnecessary. A few of the students have heeded faculty advice and performed an industrial internship for 1 semester. These students return with a completely different, somewhat chagrined attitude.

In my opinion, any engineering student should become computer and internet competent. He should have some knowledge of Pspice and layout, Proengineering or an equivalent, an ANOVA program, Matlab and its toolboxes, Labview, assembly, a compiler such as C++, and some conception of network management.

Each of the branches of engineering has their unique set of jobs. In the case of the EE, these might range from power generation and distribution to microcircuit development or chip design. Obviously, design of a final product requires expertise beyond these capabilities so that the EE will probably become a member of a design or construction team. Other members of that team will have skills depending on the requirements posed by the final product. Required skills may range from chemistry and metallurgy through environmental sciences, since disposal of the product after completing its life cycle should be part of initial planning. In order for such a team to be successful, each member must be able to communicate to the others in language they understand, so that some knowledge of the fields involved is required, there must be an ability to look beyond the "Edges".

made to desire, a reliable, safe, long-functioning, human friendly end product. Some of these requirements have been incorporated into civil and criminal laws, and some form the basis for rules of ethical conduct within professional organizations. A design or process may confer an economic advantage to a business, so laws have been erected concerning intellectual property rights which may constrain the design process. These constraints extend to designs originating in university laboratories, including student design projects. Supervising faculty have the responsibility of explaining the rules and regulations to students involved in original design projects, especially when they have arranged an outside sponsor. The sponsor must understand he has made a donation and not an investment. Otherwise, students and faculty may find themselves between university administrators and an irate sponsor.

Students usually have negative reactions to this “Edge”, but it is necessary that they understand the intellectual property rules whether in school, or when signing an intellectual property agreement when they become employed. While the student may understand the rules, the thought that anyone has a right to the product of their imagination and hard work remains quite galling. The “Edge” between engineering and legal professions can be trying, but must be understood.

Other “Edges” which can produce catastrophic engineering failures occur when implanted devices are utilized in humans or experimental animals. To most engineers, immunology is a subject written in Greek. Tissue reactions to materials meeting engineering requirements are constant, vexing, and solutions are hard to find and expensive to explore. This difficulty enters into biological fields ranging from tissue culture to membrane scaffolding to implantable devices of all types and is a continuing field of research.

I hope I have presented a case for encouraging intensive study of required courses, but also encouraging students to “Step back” and consider the environment in which a particular solution is to operate and the requirements imposed by the demands of that environment.