Teaching Philosophy

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My teaching philosophy is based on the concept of learning-by-doing. I am an advocate of active, problem-based learning strategies, including laboratory experiments, design and research projects and other hands-on activities. I believe that students learn the most when they engage their five senses and have to struggle to make sense of things. I believe in learning by discovery and the value of repeated, prolonged experiences with the materials and events associated with a topic to be learned. These principles guide me when I develop courses, laboratory experiments and undergraduate research projects. They guide me when I lead curriculum improvement efforts in the department. They guide me when I try to help future and present faculty members to improve their pedagogical skills as well as the content of the courses they teach. In this narrative, I will attempt to describe how I continue to develop and apply my teaching philosophy.

Course and Curriculum Development

EMCH 371 - Engineering Materials. During my first semester on the faculty in 1990, I was assigned to teach EMCH 371 - Engineering Materials. It was a 3-credit lecture course, but I knew that engineering materials (metals, plastics, etc) could not be fathomed from a lecture in front of a chalkboard. So, I began organizing out-of-class laboratory experiences for my students. At the same time, I sought and secured extramural funding for laboratory equipment and obtained the university's approval to add 1 credit hour for weekly laboratory sessions.

What developed was a program on Engineering Materials Education, whose goal was to improve the ability of mechanical engineers to make informed material selection decisions during design. To accomplish this goal, I revised the course and developed an integrated series of laboratory experiments. In the laboratory, a set of representative metals, ceramics, and polymers are concurrently characterized with a series of experiments that investigate their structure, properties and processing. By following the same set of materials through the same sequence of experiments, the students can grasp and retain the concepts of structure-property interrelationships, and better understand how materials compete with one another during design. This project was initiated through an NSF ILI award, and then extended through work with the NSF Gateway Engineering Education Coalition's Materials Project, which consisted of an interdisciplinary team of faculty from 5 universities. As the project leader for the Materials Project, I helped other Gateway schools to adopt parts of the USC lab sequence, and was able to adapt modules developed at the University of Pennsylvania and Drexel University to USC.

EMCH 467 - Mechanical Engineering Laboratory. In 1998, our capstone Mechanical Engineering Laboratory was in trouble. Expanding research programs had targeted the space that it occupied. The laboratory's equipment was obsolete and/or falling apart. Students went from one canned experiment to another unrelated one, week after week, and as a result had little interest in learning. Although I did not teach this course, I assembled a team of faculty, and we sought and secured the funding to improve it.

The result was a 3-year program on Experimental Design Education. The goal was to improve the students' abilities to design experiments for complex thermo-mechanical systems. We chose a 5/8 scale Legends race car as the complex system to study because it is compact, applies almost all fundamental mechanical engineering principles, and is in the realm of student experience. It brings an enthusiasm to the students, which is a tremendous asset in this required laboratory course. In the laboratory, the students progress through a sequence of experiments on the race car. They are increasingly involved in experimental design (selecting sensors, sensor locations and experimental operating conditions). The course culminates in an open-ended design of an experiment for the vehicle.

This course development project was supported by Dean's office, the Provost's office, and by 2 major grants from the National Science Foundation's Division of Undergraduate Education. Faculty at RPI read my papers on this course, and have adopted my approach in their own laboratory sequence.

UNIV 101 E - The Student in the University (Engineering Section). The engineering sections of UNIV 101 include the learning outcomes that the students demonstrate knowledge of engineering, and demonstrate the ability to use a suite of computer applications. When I began teaching this course in 1999, I immediately recognized that hands-on laboratory experiments would be an effective way to develop these outcomes.

For example, I developed an in-class experiment called "Full-Body Contact Statics" that introduces the students to Statics and Solid Mechanics. The students apply a load to a simple wood beam by standing on it. Support reactions are measured with bathroom scales and beam deflections are measured with a ruler. By varying the amount and location of the applied load, the students perform a number of experiments. Other inexpensive experiments that I developed are "Head Pressure" to reveal fluid mechanics principles, and "Resistance is Futile" to demonstrate electrical engineering concepts. After each experiment, the students have to learn to use MathCAD or Excel to analyze their experimental data. According to student survey results, students in my sections found the computer-training component of U101E more valuable than students who did not perform experiments. My students also liked that they actually saw engineering principles in action, instead of just reading about them.

EMCH 361 – Measurements and Instrumentation. For the past year, I have the opportunity to teach EMCH 361 - Measurements and Instrumentation. I have abandoned the old pedagogy of using experiments primarily to demonstrate that the theory presented in lecture is correct. Instead, I use the laboratory to drive the class. I tell my students that this class is about them taking responsibility for what they're going to learn. This has been extremely effective, but has not been without risk. The good part is that after completing an experiment, the students want to know why it came out the way it did. They want to know the theory and, having just seen it, can rapidly assimilate the new knowledge because it is meaningful to them. The risk is that they sometimes ask questions I can't answer immediately (fortunately this doesn't happen often).

I have also made a number of content changes in the course, but the most significant is that the first five experiments in the laboratory are designed to scaffold the students to develop the ability to design a simple experiment. This semester, my course will culminate in a 4-week laboratory project where teams of students must design, construct, calibrate and use a strain-gage based load cell to weigh the instructor (me). Our sophomores have never before been so challenged at the synthesis- and evaluation-levels of Bloom's taxonomy of cognition.

Curriculum Assessment and Improvement. I have also sought to improve undergraduate education from an administrative role. As the Undergraduate Director and Chair of the Mechanical Engineering Undergraduate Committee, I lead our faculty to establish an outcomes-based assessment process prior to our program's successful accreditation visit in 1999. To win faculty support for this process, I made numerous presentations at regularly scheduled faculty meetings. These presentations were brief and each focused on a different aspect of course or curriculum assessment. At the same time, I worked with the NSF-sponsored Gateway Engineering Education Coalition to bring experts on assessment to campus for seminars and workshops. In my experience, short presentations brought to the faculty can sometimes reach more people and have a greater effect on changing attitudes about course and curriculum improvement than large college- or campus-wide seminars. Therefore I believe a combined approach is appropriate. With our assessment results, I recently led our faculty through the most significant program improvements in over 30 years.

Human Resources Development

Future Faculty. I believe that my program to teach future faculty to teach will have the longest-lasting effects towards improving undergraduate engineering education. This program involves the collaboration of the College of Education and the support of two grants from NSF's Graduate Teaching Fellows in K-12 Education (GK-12) program. Over the past 2 years, I have mentored 19 graduate students and 6 undergraduates from our mechanical, chemical, computer, civil and environmental engineering programs in order to develop their teaching and communication skills, and at the same time, to enhance science education in public schools. We have designed a graduate student training program that combines formal coursework in education with service learning: my students help K-12 teachers adopt and develop state-of-the art learning materials that situate science learning in design problem solving and other experiential learning activities. The service-learning component of the course - the learning by doing - is having the greatest effect on the engineering student's growth and development as potential faculty members.

Present Faculty. An unplanned impact of the GK-12 program is that I have learned an incredible amount about teaching and learning though my interactions with my co-Pi on the project, Dr. Christine Ebert from the College of Education. I have learned-by-doing. Our partnership has been so rewarding, in fact, that we sought and received support from NSF's Bridges for Engineering Education program specifically to foster cross-college collaboration of other faculty. Through surveys and a joint lunch meeting, we helped faculty in the two colleges find common interests and prepare joint seed grant proposals. The seed grants we are funding directly addresses either pedagogy in engineering courses or engineering content in K-12.

I have been involved in faculty development in other ways, including recruiting members for the American Society for Engineering Education (I am the USC Campus Representative for ASEE). I also facilitated the "Workshop on Developing a College-Wide, Departmentally-Focus Assessment Process" at the SUCCEED-Gateway Conference in Greensboro, NC in 2000. In February 2003, I was invited by Taiwan to lead a workshop session for Taiwanese faculty and administrators, as part of the US Delegation to Taiwan on Engineering Accreditation. I am still quite taken aback by this honor.

Integration of Research and Education. I see the primary role of university research programs as enhancing the education of our students. My primary technical research area is engineering materials, with an emphasis on composites and reinforced plastics. I have used my research experiences to redesign our elective courses on mechanical metallurgy and on composite materials to include topics on advanced and emerging structural materials. Elements of my research have also enhanced our manufacturing and design of mechanical elements courses. My research has helped educate 29 undergraduates, 20 graduate students and 3 post docs. My primary goal as a research mentor is to help my advisee develop his/her problem solving skills and ability to learn independently. In these relationships, I view myself more as a coach than a professor. Through our mutual collaboration, each of us learns.

Concluding Remarks

When I was a 10th grader in Mrs. Huey's chemistry class, I mixed a few chemicals with water, then pulled out a long white solid filament of nylon. It was awesome! There it was - chemistry - and I could see it and touch it! That experiment engaged me in "doing chemistry" and made it real to me for the first time. While writing this narrative, I realized what a profound impact that single event had on the development of my philosophy of teaching and learning. Thank you, Mrs. Huey, for showing me the value of learning-by-doing.