A Message from Chair Hsu on the Fundamentals for ME Education

-an introduction to an article by Christopher Hoeber

Dear friends and alumni of the ME Department:

It gives me a great pleasure to introduce this invaluable and timely article to you, "On Fundamental Curriculum Subjects in Engineering Education" authored by Christopher Hoeber, the Chair of our department's industry advisory council (ME-DAC). In addition to be a senior executive of a leading aerospace engineering company in the nation, Chris is a visionary engineering educator. At the request of our department, he reached out to a group of young engineers (including many who happen to be our alumni) in his company in search of better ways to educate our students and make them more successful in their careers. The attached article presents some of his findings. You will find from reading his article that not only has he identified fundamental subjects in mechanical engineering education, but they are also applicable to *all* engineering disciplines. It is thus of particular value to us as engineering educators, and to you as engineering professionals.

FUNDAMENTALS for engineering education has been a buzzword advocated by many prominent educators and senior executives of major industry in the country, but few actually have offered what particular engineering curricula, such as specific courses that constitute "fundamentals." Different people have different perceptions of what the "fundamentals" are in engineering curricula. Another related question is what specific subjects involved in these courses should be viewed to be more fundamental than others. Consequently, despite persistent and strong advocacy by prominent educators and industry leaders on the fundamentals in engineering education, there has been scant practical value for engineering educators to develop curricula that emphasizes fundamentals to be offered to their students.

The lack of clear definition of "engineering fundamentals" is mainly due to the fact that engineering education covers a wide range of topics in science and technology, and hence there is large number of courses for the students to learn in the field. Additionally, there are also a great variety of engineering careers that can be pursued by our graduates. Therefore, it is difficult for anyone to identify specifically what knowledge and skills can be classified to be "fundamentals" that benefit practicing engineers in their career lives. I, personally regard those courses and subjects that I had learned in my school years that have been used repeatedly in my career life to be the "fundamentals," which include some math and science (primarily in physics and chemistry) in my lower division education, and the courses on the principles of solid and fluid mechanics, thermodynamics, heat transfer, mechanical systems design, and the skills of using math to solve engineering problems in my upper division education. I also view those courses and the related subjects that enabled me to learn the 99% of the new technologies that I have mastered now after my graduation from universities to be "fundamentals" too. The latter aspect of what we call "life-long learning experience" is of particular importance for me. From my own experience, I began my career as a practicing engineer working for major electric power generating equipment companies in both Canada and the U.S. before becoming an academician. I have "survived" and coped well with rapidly advancing technologies in advanced aerodynamics and nuclear fission technologies in the 1970s to CAD/CAM and robotics in the 1980s, the microelectronics packaging, information storage systems and mechatronics in the 1990s, to MEMS and nanoscale engineering around the turn of the century, and most recently in renewable energy and green technologies. We are now in the era of information technology with an accelerated pace of innovation and applications of wireless communication and cyber-space controls technologies. The fast evolution in emerging technologies as we have witnessed in the last 50 years have become major challenges to engineering professionals, and require them to be adaptive and excel in this era of fast-advancing technologies. My own experience and that of my colleagues and our ME-DAC members have convinced us that the only way any engineering professional can "survive" and "survive well" in this era of super-fast advancing technologies is to possess solid "fundamental" principles of math, science and engineering in their school years. Consequently, the Department has launched a major effort in the New Year to upgrade our curricula with significant emphases on the "fundamentals." This article by Chris is thus of significant value to us in this new initiative. I hope it will benefit you too in your professional career. Meanwhile, we welcome and appreciate any additional input from you in making the list created by Chris even more complete.

On Fundamental Curriculum Subjects in Engineering Education

Offered by Chris Hoeber

Chair of SJSU-ME DAC on January 25, 2014

There are two lists attached to this. The first is a list of fundamental knowledge that a well prepared mechanical engineer should know to succeed at any job. The second is a list of things that may well be taught in universities, but which are items of current interest that have been invented or developed by diligent application of fundamental knowledge; they are not fundamental in and of themselves. I have referred to everything on the first list over and over again during my 44-year career designing spacecraft.

We believe that it should be the goal of the Mechanical Engineering Department to provide its graduates with the fundamentals. They come from different areas of STEM* education; most are mechanical in nature, but some are math and some are electrical in nature, or based on physics or chemistry. (* STEM denotes **S**cience, **T**echnology, **E**ngineering and **M**athematics)

Prior to the time I was born the life cycle of most products and industries exceeded a human lifetime. Therefore, unless one was extremely unlucky, one could expect to learn to do something well and that could be your trade for the rest of your life.

Today (2014) however, the life cycle of many products is less than a human lifetime. People may have two or three or even more trades during their life. This increases the importance of fundamental knowledge. To successfully use that knowledge:

1. It has to have been taught
2. The engineer has to have had an opportunity to use it – this enables its recall later in life; we all know that in order to really internalize something, it has to be practiced

3. Even if he or she uses a piece of knowledge today, the details may be forgotten the next time they are needed. But if they have been internalized, they can easily be looked up and reapplied. It is not necessary to memorize every constant and every equation, but the successful engineer will know where to apply it, how to apply it intuitively, and where to look it up if a qualitative result is called for.

SJSU has the unique advantage that within a 20-mile radius of the school, there is world class engineering talent being applied to all of the items on the second list. No engineer can be expert in all of them simultaneously, but they can seek internships and then full time jobs in any one of those, and become expert in one or a couple of them. Students can practice in their school labs, but then SJSU should take advantage of the proximity to provide its students an opportunity to apply what they have learned, and to find their career after graduation.

Most of the items on the first list have been around since before any of us was born. But not all; the canon of knowledge has been growing slowly. Fortunately, the ability to store, search and retrieve information has been growing more rapidly, so this should not be a worry to anyone, at least for generations to come.

Think of anything you want that is not on one of these two lists. I think that it will be immediately apparent which of the two lists it belongs on. If you can check off everything on the first list, then you are well prepared for anything on the second list.

1) List of Fundamentals:
(I am sure I am leaving something off – feel free to add what I missed)

1. How to give a technical presentation and get your ideas across – how to communicate verbally and in writing, and how to listen (there is a reason this is first on my list)
2. Newton's Laws of Motion
3. Ohm's Laws
4. Kepler's Laws
5. Newton's Law of Gravitation and the Gravitational Constant
6. The Laws of Thermodynamics
7. Maxwell's Equations
8. The Archimedes Principle
9. Kinetic and Potential Energy
10. Stress and Strain
11. Yielding and Buckling

12. Compression, Tensile and Shear Forces
13. The Speed of Light and (at least) the Special Theory of Relativity
14. Differential and Integral Calculus
15. Eigenvalues
16. Conservation of Momentum
17. Angular Momentum and Moments of Inertia
18. Shannon's Theorem; the Shannon and Nyquist Limits (these are the only items on this list that I suspect some of you may not know. They are the foundations of Information Theory and, because the designers of the Ariane launch vehicle did not know them, they mis-measured the pyrotechnic shocks on the Ariane for years).
19. Reynolds, Froude and Mach Numbers
20. Turbulent and Laminar Flow
21. Gaussian, Rayleigh, Uniform and Bimodal Distributions
22. Mean and Standard Deviation
23. The Central Limit Theorem
24. The Ideal Gas Law $PV = nRT$
25. Wave/Particle Duality
26. Tools: hammers, pliers, lathes, CNC machines, 3-D printers, wrenches, levers, etc.
27. Tools: CAD/CAM, Excel, etc.
28. Boolean Algebra
29. The Rules of Algebra – associative, commutative and distributive properties of numbers, etc.
30. The basics of chemistry and materials properties
31. Dimensioning and tolerances
32. The SI Units
33. Fasteners – screws, bolts, rivets, adhesives, etc.
34. Welding and Soldering
35. -- To Be Continued --

2) **List of things that are not fundamentals**

1. PCs
2. Microprocessors
3. Jet Engines
4. Cars
5. Motorcycles
6. Cell Phones and PDAs
7. Social Media
8. Airplanes
9. Spacecraft
10. Cubesats (a wonderful teaching tool, with increasingly useful applications)
11. Gasoline, Electric or Hybrid Motors
12. Solar Cells
13. Batteries
14. Buildings
15. Wind Power Generators
16. Graphing Calculators (included on the list to illustrate fads – in my opinion a useless invention)
17. MEMS
18. Stereo Lithography (although 3-D printers are on the fundamental tools list)
19. Transistors
20. Autoclaves
21. Vacuum Chambers
22. MRI Machines
23. HVAC Equipment
24. -- To Be Continued --