EDITORIAL

And More Again on the State of Engineering Education, Part 3 of 3 – Thoughts

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In the first two parts of this editorial, I expounded on the mechanical engineering program at UMASS Lowell and my thoughts on engineering education. From the first two editorials, you should realize that I take my job very seriously and I am truly concerned about facilitating the engineering learning process. A great deal of time is devoted to bringing young engineers to a level of competency that enables them to truly think and solve engineering problems. For the conclusion of my editorial series, I want to identify some of my frustrations about the process of teaching an engineering college student verses the process of training an engineer on the job.

In education, as teachers, we strive to teach engineers basic concepts necessary for the design, analysis, testing and certification of equipment for whatever application is needed for a particular industry. We teach design concepts, methods for analysis to determine suitability for particular loading environments, and techniques for testing to validate suitability for some loading conditions. In the early stages of the education environment, some of the teaching methods center on simple development of basic, necessary skills. These involve mathematical methods for the solution of equations, utilization of software tools to predict basic characteristic responses, etc. Students are exposed to particular courses depending on their specific field of interest (chemical, electrical, civil, mechanical, aerospace, etc.). Basically all of the fundamental material is taught to freshmen and sophomores, but with a specific bias towards their particular discipline. Once junior and senior years come around, the material becomes more intense and much more closely aligned with their particular field of study. At this level, the material is taught with very clear cut problems that have very specific answers so that the students 'learn' how to apply sets of equations to elementary problem solving.

As the students start to reach the end of their undergraduate curriculum, the emphasis is shifted from learning rote skills for solving specific problems, to learning how to apply basic concepts and ideas to solve problems and how to formulate solutions to problems that do not have clear cut "answers at the back of the book." As professors we strive to force the students to "think outside the box" and to apply basic concepts, theories and procedures to solve problems that have no specific straight line answer. This is what engineers are trained to do – solve problems that have no clear cut specific answers.

Let's face it – if a problem has a clear cut, well-defined answer, then there is no reason to have a high paid engineer solve a simple equation. The task could be relegated to someone who has not been trained to such a high level of expertise. We could 'chimpify' the task (what is commonly called 'chimpification') by setting up a fixed process (what I also call the "Burger King Mentality"). Basically, the process becomes a push button approach stated simply as "Burger, fries, coke, $3.28 total, $5.00 received, $1.72 change." Bingo. No thinking required, whatsoever.

As engineering educators, we train engineering students to think about how to solve problems. Unfortunately, once engineers graduate from college, they are put into an engineering workforce where a significant amount of work needs to be done in an efficient manner. This is especially true in very large companies such as automotive and aerospace corporations where a large amount of work needs to be done on a very tight schedule to make sure that products are designed, analyzed, tested and certified as necessary. In the sequence of designing components and systems, there are a variety of tasks that have been identified in a 'process' that must be completed to fulfill a design requirement or contractual obligation. Engineers are relegated to performing tasks that sometimes have no apparent purpose – other than to satisfy a checklist of "things to do."

These large companies always attempt to form a process to streamline the endless series of tests and analyses so that the path is well defined to complete the never-ending analysis and testing that is required or mandated. The goal is to identify a process so that each part and subcomponent is subjected to the same rigorous analysis in the clearly defined path to completion of the project. The beauty of the 'process' is its clear definition, which the accountants (bean counters) can use to project cost, margins and profits. The process also helps to identify stages of a design with clear cut start and end dates, with specific numbers of hours billed to the project. The process is also the one step that forces the engineer to follow a very well defined path from start to finish, with clearly identified steps and goals, and clear cut approaches to perform the tasks at hand. In fact, the process is very similar to those early engineering problems in freshman and sophomore years where very specific problems were identified with very clear cut answers and very deterministic natures – there really were answers at the back of the book. This reduces the engineer to not needing to "think outside the box." He is only required to follow the specific steps identified in the 'process.'

But the only time a 'process' can be identified is when the task is very deterministic. Once a task can be reduced to this form, then surely 'chimpification' is appropriate. But what happens when the problem does not follow the anticipated deterministic outcome? Will the engineer be able to identify that the problem is outside the anticipated boundaries? Will the engineer know that the process is flawed and that a red flag should be raised? Or will he just file the analysis or test report into the black hole filing cabinet and check off the next box on his list of "action items?" And who is going to check the checklist? Will the checker of the checklist be insensitive to thinking, when he has been brought up through the 'process' that forces the engineer to not have to think?

This is a very scary situation. Engineers are taught to think. Professors work very hard to bring them to a level of competency in the four years of undergraduate study so that they can think through difficult problems and come up with solutions to solve those problems. Unfortunately, large companies then reduce the fully trained engineer into a machine to produce volumes of information in a very specific, well-defined process that forces the engineer to not need to think any longer.

I am worried that engineers will become very much like Dustin Hoffman as the character Raymond in the movie *Rainman*. I can see Raymond as he quickly counts toothpicks with extreme detail and precision and can determine square roots to 15 decimal places. I can also hear him display concern at the breakfast table when he says, "No maple syrup on table. Def-, definitely has to be maple syrup on the table if we are going to have pancakes." Likewise I can hear the 'process' engineer saying, "The spec says to do it this way. Def-, definitely have to do it that way," with no real understanding how or why the spec was developed.

As far as I am concerned this is a

verybad situation. I am worried that when some critical analysis or test needs to be interpreted that the engineer may not even realize that there is a problem lurking in the dark since he has lost all his ability or need to think as an engineer.

Having gotten that off of my chest, I feel a little better – but not great. Obviously, much needs to be done to improve the overall situation. Of course, there will be students who get through the system with decent grades but may not really appreciate all aspects of engineering as best as they might need. They may not remember how to do hand calculations (but they should be more than proficient with them). They may not even have been exposed to real data acquisition systems to understand the pitfalls of interpreting data (but any of *my* students who falter here will have a downward grade change for sure). And they will probably spend way too much time making pretty pictures on a CAD system (every student does). And they probably forgot all they were taught about dimensioning and tolerancing (but you don't have to be a rocket scientist to figure it out again). And I'll bet that they could make an engineering sketch by hand (but the final report will need a properly annotated CAD drawing). And will they be able to prepare a proper engineering report and make a useful presentation? And can they make a proper plot to convey engineering data (which is really important to survive in the workplace)?

I know Strether Smith's editorial hit on a sensitive note that the engineering graduates we produce seem to lack some basic skills and common sense. I take that general comment very personally. I agree to some of his statements and I feel that students need to have a firm basic understanding at a very basic level (and that appears to becoming lost in the educational process from Strether's viewpoint). But let me make a few analogies here. Students leaving college are like rookies in sports – they need further mentoring and training. Look at the great sports players – they make mistakes. Back in Part 1 I told you I was watching a playoff football game while I was writing. In it, I saw two plays in a row where the defense set up with only 10 men on the field – *two plays in a row with only 10 men on the field by a team in the playoff*!?! Didn't they learn that you need 11 men on the field in Defense 101 – how could they forget? And three plays latter, I watched a receiver running downfield who never turned back to look for the pass. Didn't they teach him that in Receiving 102 ? (As long as we are talking sports, what about those Red Sox winning the World Series?!? Go Red Sox! Begone the cure!!!) There were several plays during the World Series and baseball playoffs leading up it when, during a bunt, fly ball or other standard plays, the players on the field committed very basic flaws in field position. This was the Big League and in all these sports, these athletes are extremely high paid individuals who should not be making rookie mistakes. But they do. So maybe once in while, you can give those young rookie engineers a little break now and then and coach them along. For the most part, they do have the proper skills but may have just forgotten some very simple concepts or tools and need a little nudge to remember them. By the way, does everyone remember how to take a Laplace transform or why it is used? I know you were taught that in college, so why can't you remember it? And what about Fourier series? Can you derive the series for a sawtooth pulse? What is that you say? You need to dust out the cobwebs??? But you might be using that FFT analyzer all the time to reduce data and you might not remember the basis of this important, everyday tool. I know there are many times when I can question the reduction of data and the seasoned engineer may have forgotten some basic principle that may shed light on the results that appear confusing to him. I think that we all face situations where some of the basics have been forgotten since we haven't used them for a long time. Or, in the case of the young engineer, he may not even have realized that he was taught that in courses such as "Useless 201" or "What the Heck Do We Need This For 202," and never needed to apply it. So it is forgotten so easily. Of course that material was important, but for some reason it never hit the student's "I need to know this forever" button.

In closing, what I am trying to say is that we need to have a little bit of the old school (hand-calcs and the like) blended in with the new school (fancy wiz-bang CAD models) in the educational process since all of these tools are needed in the workplace today. We only have so many courses and credit hours that make up the entire program. We need to use all of them wisely. We can't devote all of our effort with one mode of teaching for one specific industry or generic approach common to one particular field of work. We have a very broad range of industries that will employ our students in a variety of different roles. We need to do the best we can, with the time available, to impart a basic cornerstone of knowledge so that students learn how to think and how to learn to teach themselves for future, lifelong experiences in the engineering community. That's quite a formidable task. And I know that the Rainman would agree and say, "Def-, definitely!!! S/V

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