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Engineering First: An Undergraduate Dilemma

Shehu S. Farinwata, *Ph.D., P.E., Senior Member, IEEE*
Department of Electrical Engineering
The University of Texas at Tyler
3900 University Blvd, Tyler, TX 75799, USA

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Abstract

The trends brought about as a result of computer software revolution and evolution are many and varied in just about any of the traditional engineering disciplines. A lot of such trends might be seen as a response to an interesting reversal of opportunity, which is application-driven research. Not too long ago it had been research seeking application. Experience has shown that the ensuing rush to the mouse and keyboard and the super calculator in engineering education tends to erode the once very pervasive, curious and enthusiastic, if not essential, attitude for grasping, with uncompromising rigor, the various traditional science and engineering subjects. So in the heat of a circumstance, a student might opt to escape having to review, or even gain a good grasp of vector calculus so as to solidify an understanding of electromagnetic fields hence that of circuit theory and of electric machinery, by clicking away in say, Mathematica, Matlab, Maple or any CAD package for that matter. It is not uncommon that such a student might find the application of essential circuit laws quite problematic in an ensuing course in electronic circuit analysis. Another not so uncommon instance that experience has revealed is that of the student asking if it was sufficient in a course in system theory, to use a software package in a homework in which it is required to determine the *eigenvalues* and *eigenvectors* of a simple three by three matrix. The fear being that it might be too tedious. However, another fear that has been observed was that the student's discomfort or inadequate preparation in linear algebra might be exposed. What one would expect a conscientious student to do in this case might be to do the assignment by hand thus reviewing and enhancing the understanding of linear dependencies of vectors, rank and degeneracy of matrix eigenvalues and eigenvectors, then verify the key results using a CAD package. That way the student might even discover the effect of computer round-off and truncation errors, if any, on the computed eigenvalues and the eigenvectors, and what algorithm was used in the CAD package with its associated pitfalls. While all of this click, drag and drop and press may be going on in the spirit of educational exploration, curiosity and vogue or even as a matter of necessity and timeliness, there should always be a point for researchers and educators to consciously stand back and ascertain the importance of helping the undergraduate student maintain some balance, to be well-groomed in both sound engineering theory and computation. This paper addresses the issue of this balance. Examples are drawn from the essential, make-or-break engineering courses such as differential equations and circuit theory to show the lack of mature

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understanding that could contribute in the student's loss in the race between the engineering discipline and technology.

Introduction

Experience continues to point at an alarming trend where engineering students are opting for the computer mouse alone rather than as a compliment to the traditional, analytical rigor that is paramount for a lasting grasp of engineering fundamentals. This paper is a call to engineering educators to be aware of this trend and its potential for adversely affecting, particularly new engineering programs. It is assumed here that engineering programs at older more established institutions "had paid their dues" and therefore "had known better" not to let their guards down to be consumed by this trend. However, newer programs all of which undoubtedly subscribe to academic excellence and often look towards the numerous successful model institutions as a tracking reference may still not be immuned to this pervasive trend, and for these, the stakes could be higher. The aforementioned subsets of available engineering software packages if used effectively – in conjunction with rigorous theoretical and analytical engagement, would clearly produce students that are well-rounded in engineering fundamentals and the pertinent application software. These students would be very ripe to exit into the industrial world that they have dreamed about, or even into further academic endeavors. One can argue that they may be able to get by in the industrial world with their repertoire of high-tech software competency for quite sometime. Depending on the nature of the industry, pretty soon they may find themselves in a team, in fact they will, where some serious brainstorming often involving solid engineering fundamentals might be required. Often this step would proceed any attempt at trial and error via computer simulations. On the other hand, for a student exiting into the academic environment for further education, say in engineering, we all know that there is no easy substitute for a solid understanding of undergraduate engineering. To be more specific here, it is not uncommon for a student to be given an informal test in calculus and differential equations by a faculty member if such a students goes looking for a Ph.D. advisor after having passed the formal preliminary exam. Though not too common, and some may even object to, if not question, the validity of this approach by the professor. But such a professor's point of view might be that since he would be funding the student for a long time he wanted to be sure that student is ready and competent beyond the subjects tested in the formal preliminary exam.

Manifestation of Deficiencies

We mentioned differential equations and circuit theory as essential, nurturing subjects for an electrical engineering undergraduate. More difficult subjects such as electromagnetic fields, or fluid mechanics come later on by which time some maturity level has been attained by the students. In the case of differential equation since it is all-encompassing, it is highly essential for the students to be able to solve these without too much difficulty in subsequent engineering courses toward the senior year. For instance, the "guess" method [2]for writing down the form of the particular solution of a non-homogeneous differential equation, common among senior undergraduate with complete, prior formal course in [3]differential equations, should be discouraged in general. For the students in electrical engineering in particular, it would be the lack of competence in writing down basic circuit laws first, then solving a simple system of algebraic equations. This is often manifested in exams and home works where calculator solutions might stand without a single, simple circuit equation, but with only the trade mark, e.g. “E-19” or “e-19”, or even who knows something like “☞$^{-19}$ “ of the super-calculator, tagged along a numerical answer, instead of the correct, academic, scientific notation “ 10^{-19} ”. Some representative problems in circuit analysis and differential equations will be visited shortly, and in the process, the potential pitfall areas are highlighted.

Another area where deficiencies could show up, and one that institutions should pay close attention to is in standard, national or even international exams. Educators and students alike need to realize that such exams are often closed-book, closed notes, no-computer exams. Thus all the fancy software in the world would note come to the rescue. The student will have to solve problems by hand, though some classes of scientific calculators are allowed. Thus, a student will not find, for use to solve the fundamental engineering problems, any of their favorite “technotoys” a computer loaded with Matlab, Mathcad, Maple, Autocad, ControlC, Simnon, or Visual anything, nor a mouse to use for dragging and dropping, nor a super calculator. A couple of such exams are the Fundamental of Engineering (FE) exam and later on, the Principle and Practice of Engineering (PPE) exam. In fact, in no more exam than the PPE is this true. This is why we believe serious grooming in engineering in a more traditional way is still equally important and valid, and should be continue to be taught, echoed and emphasized. The student’s inability to do well in such exams, all things being equal - except mouse missing, is the undergraduate dilemma we are talking about. Thus, we emphasize engineering first, before the fancy technologies, or concurrently at best with these “technotoys” where possible.

Take the “G” out of Diff EQ

The “G” is for “guess”; we will discuss this shortly. That so much attention is given to Differential Equations is not without bases. We feel very strongly about this. The real world is dynamic. Everything we do has some element of time in it and so a rate quantity can be attributed to it. Moreover, in engineering systems, we talk about variability, changes, robustness, sensitivity, reliability, dependability, operational envelope, and so on, all of which involve relative measures of one quantity to another. And when explain these relative measures with respect to time, we end up with time-rate quantities. These relative changes or variabilities can be modeled in terms of differential or difference equations, linear or nonlinear, lumped or distributed. We obtain a dynamical system when time is the independent variable. This is everywhere in traditional engineering and science, the behavioral sciences, and on onto biological and economic sciences. We ought to be able to study these systems by seeking solutions, and variations of solutions with respect to feasible parameters, analytically, computationally and empirically.

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Furthermore, we often go ahead and build these systems and continue to validate and test the models until satisfactory expected and projective results are obtained. This innocently mentioned process is by no means trivial or simplistic. It could be a painfully iterative process, depending on the physical significance and relevance being sought, and sometimes, expected outcomes do not result, and we go back to the drawing board, time and money permitting. The author's seeming obsession that students get a good handle on differential equations by graduation can be summed up an in-class sermon for a seniors' course in automatic control. Other engineering educators may apply it to their pertinent course.

"There is absolutely no reason or excuse why an engineering senior, an electrical engineering senior in particular, should have problems with a simple differential equation with constant coefficients. I cannot emphasize the enough the significance of differential equations in engineering. That is engineering. As I've shown you, everything we have done, and we will do starts with differential equations. From these, you get solutions, transfer functions, poles and zeros, Routh-Hurwitz stability, root locus, state-space realizations, Nyquist, polar and Bode plots, and controller designs. In the digital control domain and DSP, you deal with difference equations. Perhaps you can see my obsession with the fact that you don't get out of the door into the real world without at least a mastery of differential equations with constant coefficients – that's all we're asking you to solve. I assure you that there will be one problem on differential equations in every exam including the final exam".

What has been found most intriguing even after having taken a formal course on differential equations, students often chose the "guess method" for writing down the form of the particular solution. This should not be the case and should be discouraged. There are simple situations where the particular solution can be written down without any sweat at all. Still, the more systematic approach learned from a formal course should be adhered to. These are many and varied. Such an adherence only helps the student to master the subject and helps to build a sense of competency – an achievement on its own. As far as the type of problems on differential equations that the undergraduate student may encounter, a mastery of the method of undetermined coefficients should suffice for most, if not all, of the forcing functions of engineering undergraduate courses. In the interest of space, we will apologetically differ a very brief instructive discussion on this to another forum.

Getting Fancy with Circuit Theorems

The recommendation here is not to get fancy at this early stage. Experience has shown that this hero's attitude is exhibited immediately after the student has taken the first course on circuit theory, in say, the first course on microelectronics. Here, the student has been heavily armed with all kinds of circuit theorems, from Kirchhoff's current voltage and current laws, superposition law to the more exotic source transformations laws of Thevenin and Norton, among others. It is not uncommon to find students attempting to solve the simplest of circuit problems using some of these exotic theorems, and often have messed up woefully. As it has often turned out, there has not been any reward for this futile over-kill in terms of partial credit. Thus, the observed tendency has been to resort to these high-powered laws, rather than to prudently write down simple current or voltage equations, then solve these by hand or using a scientific calculator. Besides, these fundamental problems are the kinds that are normally encountered in certain parts of the afore-mentioned professional exams. Thus, if the first course in electronic circuits poses insurmountable challenge to the student, he or she should revisit circuit theory for immediate and honest review.

Surround Knowledge

Yes, just like surround sound audio system, you want to hear it from all angles. Here, it is stressed rigorously why the students should make a conscious effort to "surround themselves" with all of their prior engineering knowledge, including science and mathematics. The hopefully unconscious efforts by students to disenfranchise themselves from previously taken subjects such as calculus, algebra and trigonometry, geometry, physics and chemistry, and others, is at best anti-engineering. The question is then why remain in engineering if one does not think these core subjects matter? Any of these forgotten subjects could and would come back to haunt the student at a later time, frequently at the worst possible time. This is not an exaggeration. Let us revisit one more time an engineering course in which prior knowledge of differential equations is assumed or actually expected. What wrath would befall a student who wrote down the auxiliary or characteristic equation of a fifth order differential equation but could only find three or even four roots? It will be the wrath of the fundamental theorem from algebra. An n-th degree polynomial equation admits n roots. We do not even want to complicate the issue by looking for complex roots, which if present, appear as complex conjugates. How about the ability to combine two terms of sine and cosine into just one term of either sine or a cosine with possibly a phase shift? That's an exercise from trigonometry, which shows up many times in communication theory, signals and systems, circuits and systems, and control theory to mention just a few pertinent areas. Students should not find themselves wrestling with these procedures at a later stage in the undergraduate programs. The conscientious students who take the time to always surround themselves with these otherwise "sponged off" core courses are those who will find the joy of engineering. Again, these are exercises that require honest understanding and not just click, drag and drop, or the use of a super calculator.

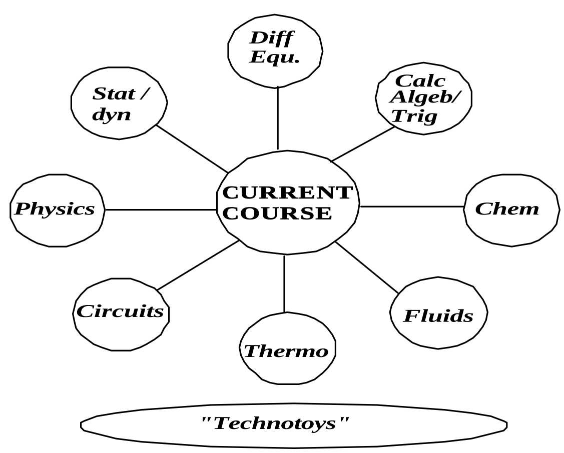

Figure 1. Surrounding Yourself with Previous Knowledge

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[5]Conclusion

This paper addresses a potentially disabling trend in the acquisition of engineering knowledge at the undergraduate level, and which needs a conscious attention by engineering educators and engineering students.

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Biography

Dr. Shehu S. Farinwata received the Ph.D. in Electrical Engineering from the Georgia Institute of Technology, Atlanta, GA in 1993. He has served as Transactions Associate Editor for IEEE Control Systems Society since 1996, and is a licensed professional engineer (P.E.) in Michigan. His most recent industrial work was as Technical Specialist with the Ford Research Lab in Dearborn, Michigan. He joined the faculty of UT Tyler, EE Dept in June 2001.