Ideas to Make Engineering Education More Efficient

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Abstract: College education of an engineering student has always been hard - lots of homework, tons of calculations, and many challenging courses. An urgent question for educators to ask is "are we giving the best possible education to engineering students?" This author believes that the answer to this question is probably a "no". Significant improvements can and should be made by making the curriculum relevant to the industry's needs, by connecting the classroom teaching to the real life experience of students, by providing hands-on experience to the students, and by using special teaching techniques. These ideas on how to make engineering education more efficient and effective are presented and discussed in this paper for professors and students alike to consider.

1. Introduction

College education of an engineering student has always been hard. There are lots of homework to do, tons of calculations to perform, and many challenging courses that are mandatory and must be taken. *How to provide the best possible education and maximize the learning during four or five years in college is a real challenge to professors and students alike.* This is a complex issue. This author believes that to address this critical issue, improvements have to be made in the curriculum and, more importantly, in the way a course is taught in the classroom. Four ideas to make engineering education more efficient and effective are presented in this paper for professors and students to consider.

Since this paper is derived, in part, from my own experience and it represents my own opinion (instead of the official position of the U.S. Nuclear Regulatory Commission), I should introduce myself. I have been working as an engineer for a total of 30 years in nuclear, aerospace, and mechanical engineering, and computer simulation. I too was once a hard-working engineering student, who spent most of the time in college doing nothing but studying _ neither efficiently nor effectively in some instances. I received my formal education in Mechanical Engineering from three universities in three countries _ a B.S. at National Taiwan University (Taipei, Taiwan, ROC), an M.A.Sc. at the University of Toronto (Toronto, Ontario, Canada), and a Ph.D. at the University of California at Berkeley (Berkeley, California, USA). In addition, while working as a full-time engineer or researcher, I have also taken several work-related engineering courses at the University of Washington (Seattle, Washington), the University of Tennessee (Knoxville, Tennessee), the U.S. Nuclear Regulatory Commission, Oak Ridge National Laboratory (Oak Ridge, Tennessee), and the Boeing Company (Seattle).

As a result, I have benefitted from a wide spectrum of professors and instructors, some good and some not so good. However, one thing is always true, namely, learning from a good professor or instructor is much more productive and enjoyable than learning from someone who is not good. I hope that the ideas proposed in this paper will be used to make engineering education not only more efficient and effective, but also more interesting and enjoyable for engineering students everywhere.

2. Four Ideas on Engineering Education

First, engineering courses (other than freshman courses such as calculus, physics, chemistry, etc.) should be periodically upgraded to reflect the industry_s needs. To achieve this goal, there should be a biannual or an annual review of mandatory and optional courses that are offered to an engineering student for a bachelor_s degree and beyond. The periodic curriculum review serves as a vehicle to allow the addition of new topics of the industry to the curriculum and, at the same time, to remove obsolete topics that have not been used by the industry for many years. A few well-thought-out criteria can be used to decide how to upgrade the curriculum. For example, a mechanical engineering course may become obsolete if the majority of the practicing mechanical engineers have not found more than trivial use of the course material in the last 20 or even 30 years. A new topic may be added to the curriculum when it has emerged as a hot issue for the industry to address or is expected to become one in the next two or three years. The periodic review should include participation not only by Department Head and professors but also by engineers (especially the alumni), who represent key elements of the industry. If a new topic cannot be readily taught by the existing faculty members, instructors from outside can be hired on contract to teach the topic; class hours can be made flexible _ including evenings and weekends, if necessary.

Second, and more importantly, classroom teaching must connect textbooks with the real life experience of the students. In other words, bring real life experience into the classroom. This area deserves much more attention than it has received**.** Connecting textbook learning with a student_s daily life experience will transform a topic that seems abstract to a lively one that a student can touch and feel. As a result, it is a very effective way for the student to understand the topic taught in the classroom. For example, while taking a course on fluid mechanics, a student should be offered the opportunity to determine whether the water flow from the student_s kitchen faucet is laminar or turbulent flow and whether the hot air coming from the student_s hair dryer is laminar or turbulent flow. While taking a course on kinematics, a student should be able to explain how and why a bicycle moves. While taking a course on machine design, the student should understand why the bicycle is so designed. While taking a course on strength of materials, the student should be asked to do a stress and load analysis for the chair the student sits on or for the bicycle the student rides. Another example would be for the student to perform a stress and load analysis for a residential house under construction, which has only the house frames (no walls and ceilings). While taking a course on heat transfer, the student should be able to explain the water boiling process in a pot on the student_s kitchen stove. While learning about electric motors, the student should be able to explain the function of various components that constitute the motor inside the students_s hair dryer, or inside an electric mixer or a blender used in the kitchen.

In addition, whenever a topic involving a hardware is taught, the students should be shown the actual hardware or its scaled model. For example, when teaching thermodynamics on gas flow through a nozzle or in a turbine, the professor should bring a real nozzle or a gas turbine model to the classroom for students to see and touch. While making engineering drawings of a hardware, the students should be given a cut-out section of the hardware to help them understand various components of the hardware. While teaching stress analysis for a steel structure, the professor should show the students a model or a color photograph of the steel structure. (A sketch of the structure on the blackboard will not provide enough information for the students to really understand the structure.)

Third, classroom teaching must include hands-on experience for a student to practice the textbook knowledge for real world applications. The hands-on experience includes building simple machines and making rough estimates of engineering quantities. Hands-on experience will further enhance the student_s understanding of a topic by applying what is learned in a textbook.

For example, as part of the classroom learning, a student should be given the opportunity to build a crude compass, to build an electric motor, and to assemble the engine of a lawnmower or a car. While taking a course on machine design, the student should be asked to try to improve the design of a bicycle, an electric motor, a small engine, and so on. After the improvement to a design is made, the student should perform hardware testing or computer simulation to verify the improvement.

Hands-on experience also includes making rough estimates of engineering quantities. For example, while taking a course on fluid mechanics or hydraulics, a student should be able to roughly estimate the surface velocity and volumetric flow rate of a small stream, using simple tools such as a stopwatch and a measuring tape. Using simple tools including a measuring tape, a student should be able to estimate the height of a tall building, the volume of a pile of sand, or the volume of water in a bucket.

Fourth, there are teaching techniques or practices to make students_ learning more efficient. There are several ways to make learning more efficient. The first technique is to summarize the important and should-know points of a topic (e.g., steady-state heat conduction) at the end of a lecture. Students are expected to understand those important points. Accordingly, the examination should focus on those important and should-know points for all the topics covered in the examination. This practice will enable a student to allocate his or her time, which is generally limited, to focus on the important points. Should more time be available, the student can then study the less important aspects of the topic, which may also be covered in the examination but in a small fraction. The purpose of this technique is to help the majority of the students to better use their limited time on the more important points of a topic; it does not discourage any student from thoroughly studying a topic by also covering the less important aspects of a topic.

The second technique is to give the students the correct answer to each homework problem, when the homework is assigned. There are pros and cons for this technique. Some professors may think that by giving a student the answer to a homework problem, the student will stop analyzing a problem as soon as he or she obtains the correct answer. As a result, the student may not thoroughly analyze the problem or the student may have got the correct answer by using an incorrect approach (that is, for a wrong reason). On the other hand, by getting the correct answer to a problem, the student will feel confident to move on to the next problem without wasting additional time wondering whether his or her answer is correct. Overall, the benefits of this technique should outweigh any potential shortcomings.

The third technique is to give students handouts before a lecture so that they can pay more attention to what a professor is saying during a lecture rather than spending a lot of time trying to copy the professor_s notes from the blackboard.

The fourth technique is to use the Internet to make professors and teaching assistants more accessible to the students outside classroom hours. Whenever students need help on homework problems or on the course material, they should be able to communicate with a professor or a teaching assistant by e-mail.

The fifth technique is to encourage students to ask questions and to seek their feedback on the teaching. Is too much material covered in a lecture? Is sufficient time allocated for questions? Is the size of the class too large to encourage the participation of the students (e.g., asking questions, providing comments, making suggestions, etc.)? Are the examination problems reasonable?

3. Conclusions

Four ideas to make engineering education more efficient and effective are presented in the paper for professors and students alike to consider. Adoption of these ideas in classroom teaching is strongly recommended. They will make learning much more interesting and enjoyable for engineering students everywhere.