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IMPROVING ENGINEERING EDUCATION

Muhammad Harunur Rashid
Professor and Director
Department of Electrical and Computer Engineering
University of West Florida, 11000 University Parkway
Pensacola, Florida 32514-5754, USA
e-mail: mrashid@uwf.edu

ABSTRACT

Engineering employers are demanding that engineering graduates must have certain skills. Each engineering curriculum must provide certain skills and abilities, and fulfill its educational program objectives within the mission and goals of the institution. Each engineering program must also demonstrate that the graduates have achieved certain outcomes.

1. INTRODUCTION

With the rapid advancements in technology and changes in the operations of business, the job functions of engineers are also changing. Industries are demanding that engineering graduates must have certain skills. The engineering programs in USA are undergoing through rigorous changes in response to meeting needs of the new century. These changes are mandated by accreditation agency (Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, EAC/ABET) and the accreditation of an engineering program will be judged with respect to defined program outcomes. Each program must have an assessment process for continuous improvement with documented results. Any well thought course required for an engineering degree should be able to contribute towards fulfilling the educational program objectives, which are mandated by the ABET criteria 2000 [1].

2. CONSTRAINTS

If you don't have the latest knowledge and skills, you're the equivalent of the immigrants coming to a new country like USA for the first time. The immigrants, who made the investment to learn how to speak, read and write the country's language, English in USA, fluently got the higher-paying jobs. Those who learned only to speak it got medium-to-low-paying jobs, and those who didn't learn the language at all got manual labor, ditch digging and other low-paying jobs.

Technology reinvents itself every six to 12 months, and waits on no one. Those who keep up and constantly seek to expand their horizons — in whatever their field — will have the best chances of getting ahead, working on their own, and switching careers whenever they choose.

We, as human beings, are born with certain limitations. Our memory is limited and we forget things very easily. If we learn and know certain things, our memory of those things decays almost exponentially unless the things are repeated. Thus, it does not matter what we teach, students will either forget or the materials will become obsolete, even be before they graduate. Therefore, we should teach things in such a way to develop student's certain abilities.

For example, we can rate the student's knowledge of the subject materials as zero at the start of the class. On the day of final, students should have the highest knowledge of the subject materials and we can rate the student's knowledge as logic 1 at the start of the exam. But, after one or two years, that knowledge would decay almost to logic 0, the same logic value as the start. The logic knowledge pattern can be described as

0 1 0

On the other hand, a student who never attended a class, the logic states of the knowledge can be described as

0 0 0

Then what are the differences between a student who started with 0 knowledge, gained the highest knowledge (logic 1) and then forgot the knowledge (logic 0), and another student who started with 0 knowledge, did not gain any knowledge (logic 0) and no knowledge to forget (logic 0)?

3. NEW KNOWLEDGE

Knowledge is the 'coin of the realm' in the 21st

Century. The New Economy needs to compete with well-educated people and the jobs will go where the smart people are. Already, the competition is being won or lost based on new forms of capital, which are knowledge based.

The principle resource driving the knowledge economy is the information: such as what we are looking for, where is the information, how we can find it, and how we can apply it for our benefits and the economy. The principle types of knowledge capital are (a) human capital and (b) intelligent capital.

4. HUMAN AND INTELLIGENT CAPITAL

The human capital is well-educated, smart people, regardless of academic discipline. Engineers, scientists and mathematicians are necessary, but they not sufficient. Human capital is renewable through continuous learning and this ability must be an integral part of a sustained economy for continual the use of the human capital.

The Intelligent capital, which is the product of research, produces intellectual property, knowledge and ideas. It is infinitely divisible. It is expandable and renewable through innovation and research.

The Southern Governor's Association Advisory Committee on Research, Development and Technology in USA has made the following policy statement [2] "Our national economies are changing. We live in a new, knowledge-based economy, an economy where human capital - brainpower drives economic activity. Education and investment in a highly skilled workforce that can respond to the demands of the New Economy are more important."

5. ENGINEERING ATTRIBUTES

The Knowledge economy will have an impact on engineering and creates challenges and opportunities. It creates a global market place that will require averaging knowledge around the world through standardized quality engineering education and sharing of knowledge. It has created global opportunity and challenges for engineering education and for advancing quality of life worldwide participation by all nations/societies. Some of the desired attributes of an engineer [3] in the global marketplace in the new knowledge economy are as follows:

- Good understanding of engineering fundamentals and design/manufacturing processes.
- Multidisciplinary, systems perspective.
- Basic understanding of context engineering is practiced in.
- Good communication skills.
- High ethical standards.
- Ability to think critically/creatively, independently/cooperatively.
- Curiosity and desire to learn for life.
- Profound understanding of importance of teamwork.

The engineering education must adapt to the changing world and to the new forms of engineering. It must also accept new quality educational standards that are acceptable by industries around the world so that engineers can practice in the knowledge economy and are transferable to anywhere in the global market place with minimum amount of difficulties.

6. ABET PROGRAM OBJECTIVES

Each engineering program for which an institution seeks accreditation or re-accreditation [3] must have in place:

- Detailed published educational objectives that are consistent with the mission of the institution and these criteria.
- A process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
- A curriculum and processes that ensure the achievement of these objectives
- A system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program

The process for determining the program objectives, outcomes, implementing the curriculum, and assessment and feedback form continuous improvements is shown in Figure 1.

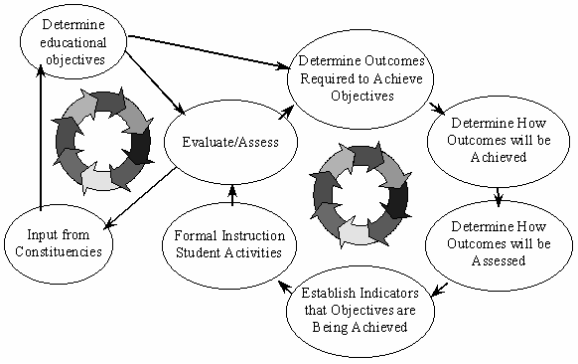

Figure 1: Two Loops of EC-2000

7. ABET PROGRAM OUTCOMES

Each engineering program must have an assessment process with documented results. Each program curriculum must provide certain skills and fulfill the educational program objectives within the mission and goals of the institution. Each program must demonstrate that the graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering [6]
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs [6]
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulates, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context.
(i) a recognition of the need for, and an ability to engage in life-long learning.
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modem engineering tools necessary for engineering practice [7].

The objectives and outcomes of a specific engineering program must be consistent with the ABET criteria within the mission and goals of the institution. Table 1 shows the cognitive level in relation to the student's learning abilities.

Table 1: Achievement of Bloom's Taxonomy of Educational Objectives in Cognitive Domain [4]

Cognitive Level	**Educational Objectives**	**Learning Ability**
# 1	Knowledge	List, recite
# 2	Comprehension	Explain, paraphrase
# 3	Application	Calculate, solve, determine
# 4	Analysis	Classify, predict, model, derive, interpret
# 5	Synthesis	Propose, create, invent, design, improve
# 6	Evaluation	Judge, select, critique, justify, optimize

8. SPECIALTY REQUIREMENTS

The ABET outcomes are not specific to any engineering discipline and all engineering graduates must demonstrate those skills. Also, the graduates must have some knowledge specific to the engineering discipline such as civil, electrical and mechanical engineering, etc.

9. ABET CURRICULUM REQUIREMENTS

Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political.

The curriculum must incorporate professional components in subject areas appropriate to engineering, which must include
(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline
(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study.
(c) a general education component that complements the technical contents of the curriculum and is consistent with the program and institution objectives.

10. ENGINEERING DESIGN

Engineering systems are becoming increasingly more complex. Thus, it is highly desirable that engineers have skills for the analysis, synthesis and design of such complex systems. A design in general transforms specifications into practical systems that satisfy those specifications. It involves many variables, and is challenging. One can approach differently to implement the same specifications, and hence many decisions must be made to achieve the specifications

In practical designs, most challenging tasks are attacked first, then the simple tasks are handled, because if an acceptable solution to the difficult problems cannot be found, then the product

development fails, and the time and money spent on easier problems are wasted. Thus, the hierarchy of engineering design process is: systems, functional block diagrams, implementations, and devices or components. The systems level design is conceptualized and expressed in terms of general specifications of functional blocks and systems integration. The design steps begin with the design descriptions, the functional descriptions, and the model/simulation descriptions.

The design process is not unique and the details will depend upon the type of systems utilized. The design process may be viewed as to

1. Identify needs
2. Generate ideas for meeting the needs
3. Refine the ideas
4. Analyze with all possible solutions
5. Decide on the action to be taken
6. Develop methods to implement the ideas.

The word 'design' has different meanings to different people in different professions. Design performed by engineers is called *engineering design*. If one asks different engineers, one would probably end up with different definitions of design. Then, what is engineering design? The ABET criteria [1,5] defines design in a broader scope as follows

"Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences and mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation."

The engineering design component of a curriculum must include most of the following features: development of student creativity, use of open-ended problems, development and use of design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, concurrent engineering design, and detailed system descriptions. Further, it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics and social impact."

11. GENERAL EDUCATION

The general education component is an integral part of an engineering program and it should be designed to develop and blend the human and social skills within the engineering concepts and fundamental principles. The general education should include only non-skill courses on human and social issues. For example courses such as English language (except literatures), accountancy and project management are not considered as general education although they may be useful for the profession. Many curriculum planers neither realize nor appreciate the importance of general education. Without human and social skills, an engineer may become like a 'robot' which is not desirable. Many professionals including engineers lack social and human skills to interact with other people of different social, ethical, political, religious beliefs, gender issues, sexual-orientations, racial and cultural backgrounds.

12. DEFINITIONS

Goals: Broad statements of desired learning outcomes (ABET "educational objectives")

Objectives: Statements of *observable* student's actions that will demonstrate attainment of goals and outcomes (ABET "learning objectives")

Outcomes: Statements of knowledge, skills and attitudes students will have that serve as evidence of achievement of goals (ABET EC2000 3a-3k)

13. CONCLUSION

The New Economy that is based on knowledge is poised for both challenges and opportunities for universities around the world. The distance leaning is a reality and plays a major role in breaking the physical boundaries for delivering courses, sharing knowledge and the management of knowledge. Engineering plays a leading role for shaping the future technology and the engineering know-how. The engineering graduates must be well prepared in the changing global competitive knowledge-based market.

Like all of us in the real world, the engineering graduates must have the ability for knowledge management such

- Ability to access the knowledge.
- Ability to locate the knowledge source.
- Ability to acquire and comprehend the knowledge.
- Ability to apply the knowledge in practical use.

- Ability to expand the knowledge into new knowledge and ideas leading to new innovation.
- Ability to share and communicate the knowledge.

It appears that the duration of engineering education should be increased beyond four years to teach the vast amount of technical development and materials. Why? It does not matter what we teach? Most course materials are likely to be obsolete in few years, even before the students graduate from a degree program. Then, why teach more? Rather, we should teach 'smart" and provide students with the necessary knowledge and skills to survive in the New Knowledge based-economy.

The effectiveness of any curriculum depends on the actual delivery of the courses within the curriculum. What are the course materials, what are being taught and how effective the teaching, how much of these materials are being understood by the students, who and how do you asses the effectiveness of learning? The key person for implementing an effective process for a quality education is the instructor/faculty. The faculty is the 'heart 'of any curriculum.

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