OUTCOME-BASED ENGINEERING EDUCATION

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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 predefined outcomes.

1. INTRODUCTION

With the rapid advancements in technology and changes in the operations of business, the job functions of engineers are also changing. 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 at a higher level of learning.

3. THEORY OF ZERO-ONE-ZERO AND ZERO-ZERO-ZERO [2]

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 tending to logic 0 within a threshold, not to the same logic value as the start as shown in Figure 1. 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)?

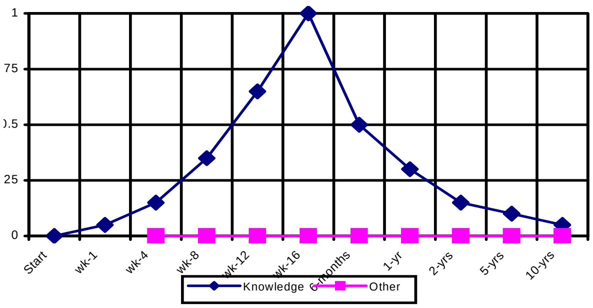

Figure 1: Student knowledge with time

4. 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 (c) intelligent capital.

5. 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 [3] “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.”

6. 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 [4] of an engineer in the global marketplace in the new knowledge economy are as follow:

- 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.

7. ACADEMIC LEARING COMPACTS

A degree program irrespective of the academic discipline should prepare graduates with discipline based abilities and professional skills to be successful in their professional careers. A proper education should develop student's abilities in the following domains:

1. Content - Recognize and apply concepts, principles and theories in the discipline.
2. Critical Thinking – Identify, formulate and solve engineering problems.
3. Communication - Communicate effectively in writing, orally and pictorially.
4. Ethics/Integrity - Make and defend ethical judgments in keeping with professional standards.
5. Project Management - Function effectively on multidisciplinary teams and develop engineering solutions that meet performance standards for costs, safety and quality.

The development of critical thinking and problem solving abilities are necessary fgood engineering education. Critical thinking [5] involves *reflection* on our beliefs, in order to *increase our awareness of them*, and the *evaluation* of these beliefs, in order to *assess our evidence for them.* Critical thinking helps us distinguish between knowledge and mere belief (or opinion or fantasy). Knowledge claims must be supported by evidence, and the evidence must exist in the proper relationship to the knowledge claim.

The academic learning compacts (ALCs) of an electrical engineering program within the above domains which should develop measurable student learning outcomes (SLOs) are as follow:

Content

- Recognize and apply concepts, principles and theories in the following areas:
  - mathematics, including differential and integral calculus, differential equations, linear algebra, and complex variables, discrete mathematics
  - core electrical and computer engineering topics: basic circuit analysis, signals and systems, and electronics, digital logic, and microprocessors
  - control systems, communications, electromagnetics, and electric power
  - discrete mathematics
  - probability and statistics
- Describe the interrelatedness of contemporary issues in a global and society context with electrical engineering solutions

Critical Thinking

- Use modern engineering techniques, skills, and tools, including computer-based tools for analysis and design of electrical engineering
- Identify, formulate and solve novel electrical engineering problems
- Design and conduct scientific and electrical engineering experiments including analysis and interpretation of data

Communication

- Communicate effectively in writing electrical engineering topics.
- Convey technical material through oral presentations of electrical engineering topics.

Integrity/Ethics

- Describe the ethical and professional responsibilities of the electrical engineer
- Make and defend ethical judgments in keeping with professional standards of electrical engineering
- Profess commitment to life-long learning to satisfy the ABET accreditation requirement.

Project Management

- Function effectively on multi-disciplinary teams
- Deliver electrical engineering results that meet performance standards for cost, safety, and quality

The students learning abilities can be measured at different cognitive level as shown in Table 1.

Table 1: Achievement of Bloom's Taxonomy of Educational Objectives in Cognitive Domain [6]

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. ABET PROGRAM OUTCOMES

The ABET criteria require that each engineering program must have an assessment process with documented results. Each program must demonstrate that the graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering [8]
(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 [8]
(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 [9, 10].

9. ENGINEERING DESIGN

Engineering systems are becoming increasing 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

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 [1,7] defines design in a broader scope as follows

Engineering design [1] 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, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs incorporating appropriate engineering standards and multiple realistic constraints. Further, it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics and social impact.

10. CONCLUSION

The New Economy that is based on knowledge is poised for both challenges and opportunities for universities around the world. 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.

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