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ANALYSIS AND OVERVIEW OF TECHNIQUES TO INCORPORATE INNOVATION IN UNDERGRADUATE CURRICULUM IN ELECTRICAL ENGIEERING TECHNOLOGY

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1. ABSTRACT

Innovation is becoming an important thrust in different aspects of academia including in undergraduate curriculum. However, the word "innovation" has multiple perceptions and meanings to different stakeholders including students, faculty, and other decision makers. This paper provides an overview of innovation process and how its associated activities are linked to a typical Electrical Engineering Technology curriculum. Additional strategies are discussed on how to incorporate different types of innovation-related activities in a typical Electrical Engineering Technology Program.

2. INTRODUCTION

Innovation has become an important focus in academia in last several years. The word "innovation" is not new to academia. Many universities have academic programs related to innovation or innovation management. However, in recent years, during the economical difficult times, we have been observing the wide spread use of "innovation" in academic world. The word "innovation" comes from the Latin word "innovare" – which means - to make something new (Anonymous, 2012). Another definition indicates innovation as the "creation of better or more effective products, services, technologies, process or ideas accepted by government, society, or market" (Tanner, 2008). There are many different definitions of innovation. Nevertheless, "innovation" in different contexts in academic world conveys a central message – things need to be done in a new way. In last 2-3 years, the number of books, websites, and blogs related to innovation has increased significantly. Industrial sectors and private companies have started using the word "innovation" along with the research and development. New

jobs are appearing with titles associated with innovation such as “innovation officer” or “innovation manager”.

The need to incorporate innovation in different aspects of an organization is increasing. Many of the companies have demonstrated their success by incorporating innovation in their product development. One such example is Apple Inc. for bringing disruptive innovative product (IPod and i-phone) to the market. It is also important to embrace innovation in different aspects of the society (education, industrial sectors, living style etc.). Along that line, we postulate that innovation can be embraced in academia – especially in curriculum, and research and development. Then, question comes, if society expects innovation to be important, are we training our students or future professionals to be innovative in their own chosen field of study? This question justifies the need of this paper.

In this paper, the author provides an overview of innovation process and how its associated activities are linked to a typical Electrical and Computer Engineering Technology curriculum. This paper is organized as follows: the first section provides an overview of a typical ABET approved Electrical Engineering Technology Undergraduate curriculum, the second section discusses the key issues related to innovation, and the third section describes a few strategies to train students in innovation-related activities.

3. CURRICULUM OVERVIEW

Accreditation Board of Engineering and Technology (ABET) has established guidelines for undergraduate curriculum in engineering technology disciplines. Within engineering technology disciplines, the student outcomes for each specific program such as Electrical Engineering Technology are also outlined by ABET. As per ABET’s program outcome for a four year Electrical or Electronics Engineering Technology (ABET, 2012a), the graduates are expected to fulfill the following requirements in addition to fulfilling the requirements of an associate degree (ABET, 2012a);

a. *ability to analyze, design and implement control systems, instrumentation systems and communication systems, computer systems or power systems;*
b. *ability to apply project management techniques to electrical and electronics systems;*
c. *ability to utilize statistics or probability, transform methods, discrete mathematics or applied differential equations in support of electrical/electronic systems.*

Moreover, the requirements for a graduate from an associate degree include hands-on competency in applying different electrical and electronics engineering principles for building, testing, operation, and maintenance of electrical or electronic system (ABET, 2012a).

A typical ABET approved Electrical engineering technology undergraduate (a B.S. degree) program requires 122-128 credits. As per the ABET criteria, the level of mathematical knowledge is above trigonometry and algebra and includes applied calculus and/or applied differential equations. The requirements for mathematics for electrical engineering technology program are different from those in engineering program. With a strong focus on applied engineering aspects, the hands-on experience in engineering technology helps students to know - what, how and why - aspects a problem. Capstone or senior design courses are generally for two semesters and involve the ABET requirements of design and problem solving.

4. INNOVATION – AN OVERVIEW

Figure 1 shows an inverted pyramid showing different segments linking to innovation. The curriculum of an undergraduate degree like Electrical Engineering Technology supports the base of the inverted pyramid. A standard Electrical Engineering Technology curriculum covers technical subjects related to core domain of Electrical Engineering Technology (Analog electronics, digital electronics, embedded system, wireless communication, power electronics etc.).

Other elective courses related to Physics, Mathematics, Communication, Statistics, Economics, and other general education topics are also included in the curriculum. Majority of the courses in Electrical Engineering Technology have hands-on experience so that the students obtain an opportunity to further enhance their understanding by conducting laboratory experiments or exercises related to the learned theories.

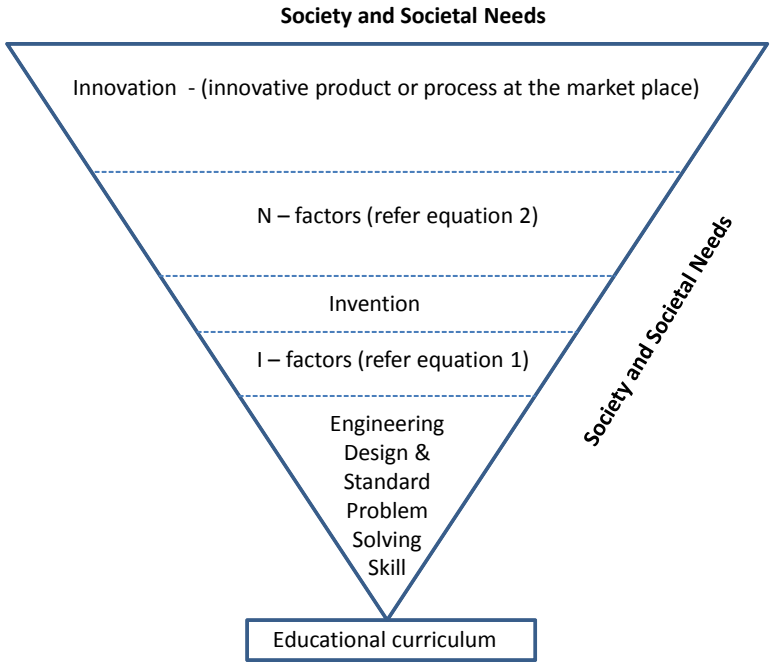

Figure 1. Proposed innovation linkage in a typical curriculum.

In any engineering or engineering technology course, subject matter knowledge is taught to the students. Through different problem solving exercises and techniques, students are trained to apply their acquired knowledge on how to solve different problems. As per the ABET guidelines, different aspects of engineering design are incorporated in various courses across the curriculum and in senior design capstone courses. Thus, from a general perspective, the "Engineering Design and Standard Problem Solving" skill becomes a foundation for the students (figure 1).

For a student to be a technological inventor, additional skills are needed beyond engineering design and problem solving skill. The author presents the following equation to describe the relationship between invention and problem solving skill. Invention refers to a novel solution for a given problem and is defined as "*any new article, machine composition, or process or new use developed by a human*" (Pressman, 2008).

Invention = Problem solving skills + I …….. (1)

Where I = invention factors or I-factors = g (q1, q2, q3, q4, q5 and q6)

g = a linear or non-linear function,

q1 = innovative and creative thinking skills,

q2 = motivation (induced or self),

q3 = available resources (time, money, and other human resources),

q4 = direct knowledge or access to resources related to intellectual property,

q5 =significance of the problem and its value in the society,

q6 = ability to identify the correct problem.

Another definition of innovation by Peter Drucker (Tanner, 2008) indicates innovation as "t*he process by which knowledge is developed and applied in new ways to the needs and materials and materials operations of society*" (Tanner, 2008) . The innovation activities are then expected to result in a product or a process, which solves a problem or addresses a need of the society. Many times, in professional domain, invention and innovations are used in a mutually exchangeable manner. That is not right. In the supply chain of innovation activities, invention is a precursor to innovation. The author argues that invention and innovation are two different entities and defines their relationship in the following equation,

Innovation = invention + N ……. (2)

where N = f (K1, K2, K3, K4, K5, K6, K7).

The function 'N" can be a linear or non-linear depending on the product and situation; K1 = entrepreneurship; K2 = social factor; K3 = economical factor; K4 = legal issues; K5 = environment; K6 = market needs; K 7 = other parameters including political, technology dynamics, and global issues.

Analyzing this above equation, the process of bringing an innovative product or process to market in a successful manner in meeting the needs of the society is very complex and involved. The author provides another metaphor to describe this process of innovation. If invention is compared with a 'seed" of a plant, the innovation is the fruit of a tree that will result from planting the seed. Planting the seed only is not enough. The seed must be planted in the right place, time, and environment. After planting the seed, the grower or the farmer needs to executes a series of operations (watering, fertilizing, managing disease, harvesting, and collecting fruits) to harvest the fruits.

Similarly, after a product is invented or discovered, many additional parameters are critical to bring the product or process to the market. All these parameters need to be in place in the right time and place. The person dealing with the innovation process must have entrepreneurial skills in recognizing, managing, and navigating through different risks and challenges. Understanding the market needs (K6) is also very critical as the product or process must time the market appropriately. With the increasing emphasis on intellectual property and patents, the person involved with the innovation process must be aware of intellectual property issues (K4). The environment parameter (K5) deals with the supporting environment in which the innovation process happens. The social and economical factors (K2 and K3) are equally critical as the other parameters (K7).

Moreover, it is important to realize that the multidisciplinary nature of skills and knowledge, a graduate of Electrical Engineering Technology program needs to be prepared in leading an innovation process.

5. ANALYSIS AND STRATEGIC CONSIDERATIONS

Existing literature (Shavinina, 2003; Tanner, 2008) suggest that invention, a component of innovation, is also directly linked to problem solving and creativity. However, like any standard university curriculum, students obtain experience in solving hypothetical problems or problems that are already defined for them. In some cases (such as class projects or senior design projects), students are required to identify their own problem. Problem identification has been identified as an important desirable skill (Shavinina, 2003). Thus, it is important to create opportunities for the students in different segments of the curriculum so that the students can learn how to identify real world problems own their own.

As per ABET general criteria (ABET, 2012b), every engineering technology curriculum including Electrical Engineering Technology trains students in a variety of problem solving experience and in engineering design (3,4). Importance of design and creative thinking related to innovation is highlighted in several literatures (Owen, 2006; Clapham, 2003). Creativity and different other forms of thinking such as lateral thinking and Six Hats of thinking (Tanner, 2008) are also linked to innovation. In a typical ABET approved electrical engineering technology curriculum, different courses employ teaching methods that engage student in different forms of thinking. If all students gets trained in creative thinking or other forms of thinking, that is difficult to know and needs additional study. However, the importance of the need for creative and innovative thinking can be disseminated to students and they can acquire additional

aspects of these skills as a part of their continuing professional development or life-long learning after graduation.

Literature also indicates the requirement of multidisciplinary education or training to enhance innovation. An ABET approved electrical engineering technology program curriculum allows a student to take courses from other disciplines including general education, liberal arts, and science in addition to taking courses related to the subject matter (electrical and electronics technology). Many universities have developed interdisciplinary engineering design projects or programs, and students from electrical engineering technology program are eligible to participate in such programs. These opportunities can provide a valuable multidisciplinary experience to a student. In addition, many universities have opportunities for undergraduate research or internships in local or regional companies. These provide a new challenging and valuable experience to the students for enhancing their innovative thinking and problem solving skills. It is important, however, for the program coordinator to identify which such opportunities provide the required challenging opportunities associated with innovation. The key issue is that the students should be to apply their acquired multidisciplinary knowledge to solve a problem in an innovative manner.

Based on the above brief analysis, it is implied that an ABET approved electrical engineering technology program provides a foundation for the students to be involved in innovation process. However, the ABET general criteria (ABET, 2012b) does not specifically focus on “innovation” or “creativity” in its (a- k) lists. However, many of the listed ABET (a-K) criteria are related to several aspects of innovation process and creative thinking skills. Thus, it might be appropriate to revisit the ABET criteria to include specific criteria related to innovation. It is, however, important that the student be aware of the innovation process and its associated benefits and cos.

The followings provide general strategic suggestions to enhance innovative thinking for the students in electrical engineering technology programs.

1. Encourage the students to consider declaring minor in “entrepreneurship” or other program such as “innovation management” or business.
2. Develop a list of internship opportunities or undergraduate research opportunities that will challenge students to exercise their creativity and innovative thinking.

3. Develop liaison with local start-up companies to create student projects where students will exercise their creativity and innovative thinking skills. Most of the start-up companies have ample technical problems to be solved. This arrangement works well for both the parties.
4. In addition to the senior design or capstone courses, develop additional electives that require multidisciplinary students to work on real-world societal problems.
5. Solicit real-world problems from companies to be considered for capstone projects by students and involve industry personnel as a mentor. The associated intellectual issue needs to be taken care of for this arrangement.
6. Develop modules related to innovation and creativity and incorporate those in different courses throughout the curriculum.

6. SUMMARY AND CONCLUSIONS

This paper provides a general overview of the innovation process and how the associated activities are linked to a topical ABET approved Electrical Engineering Technology. The ABET approved Electrical Engineering Technology program provides a foundation for a graduate (B.S.) of Electrical Engineering Technology program to be prepared and involved in the innovation process. Additional considerations are recommended to review the ABET criteria to specifically include different innovation related activities. The paper provides additional strategic suggestions for consideration by interested programs. The discipline of "innovation" is vast and complex. Thus, the future work will focus on how to incorporate innovation activities in specific courses.

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