AC 2008-1140: THE DEVELOPMENT AND DEPLOYMENT OF AN ENGINEERING TECHNOLOGY CURRICULUM TO COMBAT ENGINEERING GLOBALIZATION

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The Development and Deployment of an Engineering Technology Curriculum to Combat Engineering Globalization

Abstract

The newspapers and recent popular books are heralding the era of globalization in a variety of fields the least of which is the fields of science, engineering, and engineering technology. This conference paper advocates the opinion that an engineering technology curriculum should focus on the following study areas: Energy, Bio-Engineering and Bio-Technology, Building Engineering Services, Industrial and Robotic control, Security, Entrepreneurial Product Development, and Transportation in order to provide worthwhile student outcomes and hence satisfy employer objectives as defined by the ABET criteria established in 2000. Much detail is given to substantiate the need for such areas of expertise on behalf of the Engineering Technology student.

It is thought by many sources including the authors and members of the Industrial Advisory Board at this institution, that these areas of study will continue to provide a strong foundation upon which to build a relevant, substantive and yet, a flexible curriculum as reported here. This conference paper will describe these global engineering study areas and the potential development of a curriculum that would promote these areas of engineering technology.

Background

A careful and constant scrutiny of the following,

1. Local and national news
2. Curriculum changes in various engineering technology programs throughout the country
3. A survey of the recent placements of our own ET graduates and the present engineering positions of our evening, part-time students
4. Meetings with the faculty and Industrial Advisory Board members have identified seven areas or “pillars” of engineering technology education that can well serve the graduating student in this era of engineering technology globalization. The students in any engineering or engineering technology program student should be well prepared to fill engineering technology positions in the following engineering specialization areas of study:

1. ENERGY
2. BIO-TECHNOLOGY and BIO-ENGINEERING INDUSTRY
3. BUILDING CONTRACTING ENGINEERING SERVICES
4. INDUSTRIAL CONTROL
5. SECURITY
6. ENTREPRENEURIAL PRODUCT DESIGN AND DEVELOPMENT
7. TRANSPORTATION
Most recently the topics of globalization of science, technology, and engineering have been delineated in such popular works such as “The World is Flat,” by Thomas Friedman, “A Whole New Mind Moving from the Information Age to the Conceptual Age,” by Donald Pink. The former work in particular has been the focus of considerable attention in academia as well as the ASEE organization where the Keynote discussion in the 2005 Annual Conference noted the trends on engineering graduation rates.

The full-time as well as any adjunct faculty teaching in an engineering technology curriculum should be focused on administrating course lectures, homework assignments, course term projects and classroom instruction via worked examples in these areas. It is strongly suggested that these areas of study will continue to provide a strong foundation upon which to build a relevant, substantive and yet, a flexible curriculum that will be as immune to the globalization effects in engineering as any curriculum can be. By immunizing one self against engineering fields of study that can be deployed “off shore”, the engineering technology student can be somewhat assured of a productive, valued, and continuous career in his/her chosen field of study.

A detailed description of each of these areas of specialization is provided in this paper. The paper also provides some suggestions as to how to quickly implement these specialization areas without incurring drastic changes in an established curriculum in electrical, computer, and mechanical engineering technology.

Details of the Seven Pillars to Combat Globalization of Engineering Careers

**Energy Specialization**

Engineering and engineering technology students should be well prepared to pursue careers within the energy specialization area. This specialization includes the design, fabrication and operation of mechanical power systems, electrical instrumentation and computer control and monitoring, data acquisition, transmission, and database storing for prime electric power, renewable and advanced energy, and cogeneration systems. Permitting any thoughtful consideration regarding the self-sufficiency needs of a sovereign country, it is clear that what makes a nation great and keeps that nation sound, is a ready supply of energy. This commodity fuels that nation’s industry which in turn employs its citizens and is thus essential to a nation’s competitiveness and survival in the 21st century. The fact is that advancements in conventional and/or renewable energy systems can not only be researched but also developed within the borders of the United States. Thus, the “fruits” of this research and development will also be maintained within the borders of the United States. An investment in instruction by the faculty and in study by the students in an energy-based curriculum will help assure productive careers for interested students.

**Bio-technology and Bio-engineering**

This includes the design, prototype testing and manufacturing of mechanical, electrical and computer-based diagnostic, monitoring, and administering instruments and systems. The continued scientific exploration of biology in the 21st century and the extraordinary advances made within the relatively short time since the discovery of DNA and most recently the mapping
of the human gnome can be compared to the advances made in physics during the turn of the 20th century. The only difference perhaps is the speed in which these developments have and will continue to occur. In the mists of these developments is the need for engineering and engineering technologists who can work along side the scientists to perfect efficient processes in the development of the necessary technology. While the manufacturing of the products of this biotechnology could be performed off shore, the research and development, prototype testing, human trials and the design of the electro-computer-mechanical systems will remain on-shore.

**Building Contracting Engineering Services**

Every developed or developing nation must anticipate the growing needs of its population. With this growth comes the need for more industry and therefore more residential, commercial, industrial, and/or municipal buildings to support that increase. The fact remains that the construction of a building of any nature can only be done with the work of qualified engineers and engineering technologists. It is also true that, in the 21st century the building engineering services requires talent in many disciplines, particularly electrical, computer, civil, and mechanical. These engineers and engineering technologists must be able to provide the design, selection, installation, and maintenance of mechanical, electrical and computer systems and sub systems that are essential for the habitability of buildings. This is especially true for buildings that must serve the biotechnology industrial sector and, in the era of energy efficiency and “green buildings” (see items 1 and 2, above) must involve some aspect of energy efficient utilization, energy conservation, and/or renewable energy. Clearly every building that is designed for US standards will require competent engineers and engineering technologists and the ultimate results of the planning is a building that will likely be built in the United States. The building engineering services industry is almost by definition a non-globalization affected career opportunity. Thus, an engineering and engineering technology curriculum must accommodate the needs of this industrial sector.

**Industrial Controls**

Virtually every mass produced product is either assembled, transported from process to process on an assembly line, and/or inspected by programmed (including Programmable Logic Control, PLC), industrial controls. 21st century robotics as well as modern energy generation systems all must utilize industrial controls. Designing and/or programming industrial controls is one of the engineering areas of study that is virtually universal in their application to all of the engineering pillars of study that are being promoted for combating globalization. This technology often leads to a proprietary design for the operation of a mechanized system; even when that mechanized product eventually is manufactured offshore. Thus, competent engineers and engineering technologists are needed for this field of study and will be needed despite the globalization of more and more products.

**Security**

The concerns for homeland security in the era of post “911”, combined with the universal need for business and personal software security in almost every aspect of human communication compels the instruction of computer security programming, particularly when housed within
mechanical and electrical systems. Such systems may be found in military and paramilitary products. Clearly such security-based systems are inherently anchored to their development and use within the United States and must be driven by competent engineers who are instructed in relevant engineering and engineering technology students.

**Entrepreneurial Product Design and Development**

The popular books by Thomas Friedman and Donald Pink provide bright and focused spot lights to the need for continuous involvement of our students in entrepreneurial enterprises. Entrepreneurial enterprises includes the application of a market driven, design process methodology that can provide a cost effective and the timely development of new products that are particularly used in the five areas listed above. The entrepreneurial spirit is not new in the United States but the engineering student must be continually fortified with the understanding that he/she can be the strongest agent in keeping their full employment for a lifetime in productive engineering. By being the “boss” of a product development, even if the manufacturing of that product is done offshore, the engineering technology student will be productive and enjoy a self-efficacy as a result of their entrepreneurship or entrepreneurship that is virtually immune to globalization efforts by even the same management that employs them.

**Transportation**

The commercial and private transportation sector is a major consumer of energy, particularly fossil fuel energy that has is not renewable. The engineering of more advanced and energy efficient transportation for personnel as well as freight will be a major industry given the intensive demand that transportation has on energy needs of an industrial country that needs to stay competitive. Given that the design and development of a transportation device is a major product, the development of advanced energy systems for the transportation industry(s) combines the student’s talent in all of the previously mentioned areas of study.

**Curricula for the Seven Pillars**

**Curricula for the Seven “Pillars” that combat the Globalization of Engineering**

Each school or college of engineering technology must prepare adequate curricula to promote these seven “pillars” of the student’s education in this era of engineering globalization. Examples of such curricula in each of these categories are given here. Certainly virtually every course that the undergraduate takes towards his/her degree can contain some aspect of instruction in these seven pillars. This can be done by a concerted effort on the part of the faculty, regardless of discipline, to introduce worked examples, homework problems, and mini-projects that focus on any one of these areas of study. The faculty must be encouraged to do so.

**Energy Pillar**

Thermodynamics: Introduces the general theory of heat and matter. Discusses the first and second law of thermodynamics for open and closed systems. Applications include nozzles, compressors, heat exchangers, turbines and internal combustion engines. Topics include energy-
transformation principles, availability of energy, and properties and processes for pure substances, liquids, and ideal gases. Also covers thermodynamics properties using tables and charts, mixture of fluids, vapor cycles, power cycles and refrigeration cycles.

Heating, Ventilation, and Air Conditioning: Introduces air-conditioning principles, including psychometrics and heat pumps. Topics include calculation of heating and cooling loads in accordance with ASHRAE practices; principles of gas compression; analysis of vapor compression; refrigeration systems; low-temperature refrigeration cycles; and absorption refrigeration systems.

Power Generation: Explores electrical power generation by thermo-mechanical, electromechanical, nuclear, and hydraulic systems. Emphasizes the analysis of thermodynamic cycles as well as the practical deviations from related ideal processes. Considers accessory and auxiliary equipment used in such systems. Studies design, performance, economic factors, and public issues affecting electric power generation.

Renewable Energy Power Applications: This course will concentrate on the use of renewable energy resources to generate thermal and electrical power for residential or commercial applications. The course will outline the thermodynamics involved in the solar energy and hydro energy power generation.

Energy Conversion: Introduces magnetic aspects of rotating machines and transformers. Operating characteristics of DC generators and motors are developed. Electric power generation is demonstrated using synchronous generators. Transmission of power at high voltage is introduced by application of three-phase power transformers. Induction motor characteristics are developed. Various single-phase motors and machines such as servomotors, stepper motors and split-phase induction motors are introduced. Problems solutions will use Matlab.

Basic Power Systems 1: Presents fundamentals of single-phase and three-phase power systems. Introduces symmetrical components and sequence networks, two- and three-winding power transformers modeling, and the per unit system. Explores calculation of power transmission line Examines modeling and steady-state operation of transmission lines.

Fuel Cells: Principles and Technology: Examines the underlying thermodynamics and electrochemical principles of energy conversion through fuel cells including oxidation, free energy, and standard potential of the cell. It covers system, elements, and performance characteristics, polarization and voltage output. It studies regenerative fuel cells, and dissociation. It presents the classification of fuel cells and its applications. Special emphasis is given to the study of hydrogen fuel cells. It discusses recent technologic innovations and applications of fuel cells in transportation vehicles, biomedicine, and industrial and domestic power generation. It discusses technologic issues of fuel cells, and presents trends, forecasts and impact of this technology in areas of energy generation, conservation and the environment. Students are required to complete a design project

Hybrid Vehicles Technology and Design: This course imparts the science and technology of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV). It covers the mechanics, power and propulsion of vehicles for terrestrial transportation. It discusses fundamentals and design of batteries, fuel-cells and DC machines, three-phase AC machines, Induction machines,
Regenerative braking, Permanent Magnet Machines and Switched Reluctance Machines. It studies electric drive components, the EV transmission configuration and EV motor sizing. Students are required to complete a design project relative to EV and/or HEV design.

**Bio-technology and Bio-engineering Pillar**

Measurement and Analysis: Introduces students to mechanical measurements, instrumentation and experiment data. The principles developed in class are applied in the laboratory and technical report writing is required. Team based Laboratory experiments utilize statistical techniques in mechanical measurements of temperature pressure, force, deformation, strain, and rotational frequency.

**Building Contracting Engineering Services Pillar**

A student chapter of the Mechanical Contractors Association of America was established at the University. This national organization provides an amazing amount of help to the students who are interested in getting into careers that involve the building engineering services, including specification, purchasing, installation, start-up, and maintenance of these systems.

**Industrial Controls Pillar**

Industrial Control Systems 1: A lecture-laboratory venue that: Introduces operational safety. Examines the concept of the Programmable Logic Controller (PLC) and its associated I/O elements. Works with various manufacturers PLCs while understanding coding concepts in Relay Ladder Logic (RLL). Examines distributed I/O and its applications. Examines the concept of the variable Frequency Drive (VFD). Weekly student design projects are required as the concept of team design is utilized. A final team project would be required.

Industrial Control Systems 2: A lecture-laboratory venue that is a continuation of ICS-1, introduces operational safety. Additionally, this course examines the concept and application of an alternate PLC based system in addition to the operation and programming of HMI (Human-machine Interface) devices. The course also utilizes variable Frequency Drive (VFD) concepts garnered from ICS-1. Previous experience with a high level language such as C or C++ is required. Weekly student design projects are required as the concept of team design is utilized. A final team project is required.

**Security Pillar**

CCNA™ Security and Virtual Private Networking: This course focuses on network security and the use of Virtual Private Networks (VPNs) as an adjunct for maintaining network security when remote users require network access. Covering local and wide area networks, the course describes the use of firewalls, MZs, honeypots, screened subnets and secure subnets. The course covers the costs and performance tradeoffs when security is implemented using a variety of hardware and software techniques and covers issues related to security in computing and concepts of secure communications. VPNs are examined as a means of providing secure
connections for remote users. Laboratory exercises supplement the coursework as various types of network security issues are exposed, analyzed and mitigated.

Lab covers topics from the course using design, installation/troubleshooting and configuration activities

Computer Security: Covers issues related to security in computing, including the history of security, encryption techniques and applications, secure communications, and software protection. Other topics include software verification and validation, designing security into the hardware, and products currently available for securing systems and data. These subjects will be addressed in terms of privacy as well as reliability.

Entrepreneurial Product Design and Development Pillar

The University has established a School of Technological Entrepreneurship, which has as its Mission the instruction of students to develop their skills in promoting entrepreneurial products that have a strong technological base. The students can enroll in an academic minor in the new School curricula regardless of their major. The curriculum culminates in a Capstone-like product development.

In addition to this new School the students take select from a number of technical electives such as the following.

Engineering Economy: Studies the economic concepts that deal with the production, distribution, and consumption of commodities. Topics include economic growth, supply and demand, resource allocation, and income distribution. Focuses on the use of economic principles to develop accounting concepts, to define assets, liability, net worth, and additional topics related to engineering economic analysis.

Numerical Controlled Machines I: This course is designed to be an introduction to Mastercam vX, featuring numerical control part programming. Emphasis will be based upon programming 2-axis and 3-axis drilling, milling, and turning CNC machines utilizing the CAD/CAM laboratory.

Mechanical Design: Introduces the principles of mechanical design, the design process, design factors, creativity, optimization and value engineering. Examines properties and selection of materials, stress concentration, combined stress, theory of failure, impact, and fluctuating and repeated loads. Design methodology is applied to products, processes and equipment. Further study includes design of fasteners, screws, joints, springs, bearings and gears.

Capstone Design Project: Students from the CET, EET and MET disciplines come together to work effectively as a team to implement the project specifications and design developed in the Capstone Preparation course. Students are expected to apply knowledge from a variety of domains to formulate a plan of attack resulting in the complete solution to design and system problems. Results should culminate in the creation of a working prototype along with a final report and oral presentation by team members.
Topics in Manufacturing Technology: Focuses on special or advanced topic areas that are of particular interest in the manufacturing area. *Prerequisite:* Permission of faculty advisor.

**Transportation Pillar**

Vehicle Engineering and Design: Vehicle Engineering and Design will focus on the preliminary engineering and design of a new vehicle. Specifically the student will be studying the main vehicle sub systems including: power plant and transmission, brake and suspension, exterior and interior esthetic and functional design, exterior aerodynamic drag forces, engine controls and vehicle dynamic modeling. The students will be placed into System Teams that will be responsible for one of these sub system design areas. *Prerequisites:* Graphics 2, Dynamics, Thermodynamics or Fluids (or Heat Transfer).

Hybrid Vehicles Technology and Design: This course imparts the science and technology of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV). It covers the mechanics, power and propulsion of vehicles for terrestrial transportation. It discusses fundamentals and design of batteries, fuel-cells and DC machines, three-phase AC machines, Induction machines, Regenerative braking, Permanent Magnet Machines and Switched Reluctance Machines. It studies electric drive components, the EV transmission configuration and EV motor sizing. Students are required to complete a design project relative to EV and/or HEV design.

**Assessment**

The student evaluations for these courses have always been high; perhaps because many of these courses are technical electives that the students voluntarily choose to take. It has also been determined that many of the cooperative education assignments have the primary business areas of interest in one or more of these study areas. After graduation the students also have been found to identify companies that have their primary business interest in these pillars. Anecdotal comments from students to the faculty have also confirmed that the academic direction that the faculty gives to the student by focusing on these areas of study have been useful in the student’s employment opportunities and choices.

**Summary**

As shown by the examples given in this paper, defining an appropriate set of curriculum “pillars” and a related set of courseware to support these pillars will go a long way towards supporting the concept of appropriately deploying a curriculum that can truly aid in combating engineering globalization. While offshore “cheap labor” and the continuous quest for greater corporate profits seems to be the current trend, appropriate steps can and should be taken by U.S. universities and colleges to assist in allowing our graduates to maintain a sense of job opportunity and viability here in the United States. What is suggested here is a map that can be used to help with this problem. Initiating continuous dialog with industry representatives such as members of Industrial Advisory Boards can go a long way toward defining guidelines for appropriate academic curriculum in the future. What has been presented here is not an “end-all”
solution but simply a path that this institution’s technology program has taken to initiate a preemptive strike against this serious globalization issue.

Bibliography