Homegrown Engineering: The Development of Regional-Targeted Engineering Curricula That Reinforces Existing Programs in Florida

Walter Rodriguez, Prof. and Dir., Inst. Tech. Innov., Florida Gulf Coast Univ., Ft. Myers, FL 33965, wrodrigz@fgcu.edu
Richard Hetnarski, Professor Emeritus, Mechanical Engineering, Rochester Inst. of Technology, 632hetna@rti.edu
Bohdan Wojciechowski, Professor Emeritus, Chemical Engineering., Queen's Univ., Kingston, Ont., bohdanw@aol.com
Janusz Zalewski, Assoc. Professor, Computer Science, Florida Gulf Coast Univ., Ft. Myers, FL 33965, zalewski@fgcu.edu

Abstract *— This paper presents recommendations for designing engineering curricula in a newly announced School of Engineering at the Florida Gulf Coast University. The essential idea behind the recommendations is called "homegrown engineering" and relies on seamlessly interlinking academic programs with the needs of the region while maintaining a global perspective. The desired outcome is the production of graduates who would serve the local community --- and contribute to the economic diversification and growth of the region ---while projecting their engineered products, processes and systems globally. Four undergraduate engineering programs considered crucial in contributing to the local service-oriented economy are discussed: civil-environmental engineering, bioengineering, engineering management, and software engineering. Selected elements of the innovative program recommendations are presented while integrating the fundamental (traditional) principles of engineering education ---a challenge, but quite an opportunity.*

Index Terms *— bioengineering education, engineering management education, civil and environmental engineering education, software engineering education*

INTRODUCTION – HOMEGROWN PROGRAMS

It is widely recognized that engineering education and entrepreneurship fosters economic-development and helps to diversify the economy. But, until now, Southwest Floridians were unable to pursue engineering education in the region other than via online courses delivered by Florida Engineering Education Delivery System (FEEDS).

According to a recent study [1], *Southwest Florida was the largest metropolitan region in the United States without an engineering program.* An endowment from the Whitaker Foundation (and other gifts) is facilitating the incubation of a School of Engineering in its College of Business [2]. During the summer of 2004, a prestigious national team of engineering educators and practitioners were consulted. The team recommended three initial undergraduate degree programs: *Bioengineering*, *Engineering Management*, and *Civil/Environmental Engineering*, and one future program in *Software Engineering*.

The research question in this paper is: What approach (or philosophy) should be followed in developing engineering education programs for the 21st century? The authors advocate an approach called *Homegrown Engineering* [3] that satisfies regional needs while maintaining a global perspective. Rather than replicating existing (traditional) engineering programs in the State of Florida, the authors propose targeted engineering programs that meet the real economic-development needs of the Southwest Florida region with a socio-economical World view; for instance, a civil-environmental engineering program with water-resources and sustainable development foci; an engineering management with a construction and service-manufacturing foci. Furthermore, there is a need for a bioengineering program with a biomechanics/biomedical focus that addresses present and future needs and that links with the new biotechnology program at FGCU. Also, there is a need for a software engineering program with quality assurance and networking emphases.

Homegrown (regional, customized, highly adaptive) engineering programs can help the local industry react quickly to global competitive challenges—including engineering off-shoring and outsourcing. There are numerous benefits to having engineering faculty researchers available to the agricultural, construction, health, hospitality, information-technology, real-estate and clean-manufacturing industries in the region.

An important curriculum-design consideration is meeting FGCU sustainability mission. Fortunately, industry leaders---such as, the Accreditation Board for Engineering and Technology (ABET) and Industry Advisory Council (IAC) ---have indicated that sustainable development is a prevailing economic, environmental, and social concern in engineering education [4]. Succinctly, engineering students at FGCU must be prepared to design for sustainability.

The following sections explore new ways to implement highly-adaptive, targeted, sustainable, engineering programs. As indicated earlier, each program (or courses) must address socio-economical regional needs *while keeping a global perspective in each subject matter*. In addition to the technical content, the authors advocate incorporating case methodologies and highly-adaptive project-based approaches, as implemented in the information systems program at FGCU.

UNDERSTANDING SYSTEMS INTEGRATION AND ADAPTIVE PROCESSES IN ENGINEERING MANAGEMENT

Managing complex technological projects is an essential engineering activity. In fact, the American Society for Engineering Management (ASEM) estimates that two-thirds of the engineers' career is spent in project management activities. Engineers are devoting most of their time to planning, organizing, supervising, allocating resources, and leading and controlling operations and activities. However, most engineers are not adequately educated in these areas. Developing an effective way to teach and learn engineering-management principles is essential. This section proposes an integrated/systems approach to engineering-management (EM) education [5-6].

Although the need to provide integrated/systems approaches have been well documented, EM programs often offer an isolated menu of courses, such as "planning and scheduling," "risk management," "operations research," for instance. Rather than exploring EM as an integrated, systems-oriented, holistic program of study, traditional programs focus on courses taught by subject experts. Further, engineering-management curricula have also focused on specific fields, such as Civil, Chemical, Construction, Industrial, Mechanical and Software Engineering, while ignoring the communality of engineering-management techniques. The EM field lends itself to broader/adaptive approaches, particularly, in rapidly-changing fields such as biomedical engineering, biomechanics, sustainable-development, mechatronics and nanotechnology, among others. Highly-adaptive EM education is needed; that is, a study of systems integration as well as the adaptive processes used in conceptualizing, simulating, implementing and testing products and systems.

Timely project management is critical when delay in project completion causes significant reduction in sales of products or payment of penalties. The proposed adaptive approach views project management as an uninterrupted process: continuous communications, analysis, and decision-making resulting in the possible detection of problematic tasks and avoidance of delays. "Adaptive" project management means that a project manager/or an agent acting on behalf of the project manager constantly monitors the status of project tasks and resource allocations, identifies problematic tasks as early as possible, and makes corrective (sense-and-response) changes of the project plan, rather than waiting for problems to become a problem. The adaptive project management approach goes a step further, and analyzes situations as to provide the project manager a set of alternative solutions without hindering his/her autonomy.

The following adaptive EM program is presented to foster a discussion, rather than proposing a defined solution. Like engineering design, engineering curricula should be an adaptive, evolving process based on needs and wants. The proposed idea is to offer concurrent subject areas (course-clusters) of relevant knowledge in a sequential fashion (one course cluster at a time). Some reader may think of it as one "course" at a time. But, each course-cluster is offered by more than one faculty member along with engineer-practitioners in the proposed program. So, students will be exposed to academic and professional views as is done in architecture design studios. Each course-cluster may last one to four months, depending on the content, cases and assigned group projects. An outline of an Adaptive Engineering Management Program is presented below (does not include "general education" or "core engineering" requirements).

Cluster 1 - Managing Engineering Processes - An overview of the engineering conceptualization, simulation and implementation processes. Understanding of the methodologies, techniques and tools used in managing project resources, such as, people, materials, money (budgets), time (schedules). The course presents a methodology for designing and building/manufacturing products and systems----an adaptive method, beyond intuitive or rule-based approaches. It discusses the best engineering-management practices and principles for conceptualizing and developing successful projects. It explains the development of project plans—including orientation on the computer-aided design and planning and scheduling software packages. Students develop a preliminary plan for an local engineering project and conducts a group oral presentation. Case analysis of engineering projects in the region.

Cluster 2 - Engineering Simulation for Managers - This continuation course explores the modeling and simulation of the products, systems and processes. Since a product idea rarely springs forth complete and ready to go, realizing the idea---that is, turning it into a commercial product, system or process requires development. This course discusses the various methodologies to simulate the product and its associated processes. Engineering development requires analysis of the potential configurations, structures, architectures, procedures, strategies, markets, partnership agreements, and so on, until a satisfactory design is found. Such consideration and experimentation can be done mentally (intuitively), or by drawing on a napkin (informally), or more logically using engineering or financial analysis, revenue/cost/asset/operational business models, computer simulations, and other quantitative and qualitative management practices and techniques. In any case, only rarely is the result of the first development effort completely satisfactory, perhaps the product, process or process will be too difficult to develop, too complex, or too costly to implement, maintain, or sell. So, once again the product idea goes into the cycle of developing, testing, redeveloping, implementing, and re-testing. Succinctly, the methodology advocated in this course provides a framework for guiding the engineering development process [7]. Case analysis of engineering projects in the region.

Cluster 3 - Project and Operations Management - Engineering Operations are critical to the implementation and execution of business systems and processes. This course discusses the concepts, principles, problems, and practices of project and operations management. Emphasis is on managerial processes for achieving effective operations in information-economy service organizations. Topics include advanced planning and scheduling (beyond bar charts and CPM), operations strategy, process design, capacity planning, facilities location and design, forecasting, production scheduling, inventory control, and total quality management and quality assurance. The topics are integrated using a systems model of the operations of an organization. Case analysis of engineering projects in the region.

Cluster 4 - Engineering Operations Management - Systems methodology in industry. Optimization methods, such as linear, integer, and dynamic programming; as well as elementary game and network approaches. Emphasis will be placed on the modeling and formulation of problems and the economic interpretation of results. Case analysis of engineering projects in the region.

Cluster 5 - Engineering Financial and Cost Analysis - Fundamental concepts and methods of engineering financial and cost analysis. Understanding the relevance of financial and managerial accounting to the effective management of engineering and technology projects. Evaluation of economic feasibility of large scale engineering systems. The course has been designed to develop the student's knowledge, analytical skills and communication skills in the area of financial information-management. Specifically, this course will give the student tools to analyze a company's financial position relative to the industry, apply time value of money concepts to business cash flows, evaluate the acceptability of a short-term and long-term financial decision, understand the relationship between capital structure, risk, and the cost of capital, and improve communication skills. Case analysis of engineering projects in the region.

Cluster 6 - Engineering Administration and Entrepreneurship - Management of engineering professionals, including selection, performance, termination, and multicultural team situations. Organizing and motivating people, and controlling activities. Managing change, development, design, and implementation activities. Directing projects, improving quality, and engineering ethics. Starting, organizing, and administering engineering project. Engineering innovation, technological strategy and forecasting, techno-entrepreneurship and entrepreneurship, organizational change, capitalization, and patents and trademarks. Case analysis of engineering projects in the region.

Cluster 7 - Engineering Statistics and Quality Management - Quality management in engineering and technology. Application of statistical estimation and hypothesis testing methods to selected problems in engineering, such as quality control, acceptance sampling, design of engineering experiments and determining statistical validity of engineering data. Case analysis of engineering projects in the region.

Cluster 8 - Engineering Decision and Risk Analysis – An introduction to design and project evaluation methods, in the context of construction and clean-manufacturing. Provides an organizing framework for dealing with unstructured problems and for planning the synthesis, analysis and evaluation of solutions. Includes introductory material on engineering decision/risk analysis, reliability and maintainability as design parameters, and technological forecasting. Case analysis of engineering projects in the region.

Cluster 9 - Capstone in Systems Engineering Integration and Management - Overview of concepts and methods of integrated systems engineering and management. Consideration of life cycles, requirements, and configuration and cost management. standards, metrics, architectures, integration, and evaluation. Survey of relevant tools and techniques and their relationships to effective systems engineering management. This final capstone course explains a systematic-approach to the science of project execution and applies the key principles and methodologies learned. Students complete and implement their plan. Provides culminating experience in which students develop mini-projects and case studies requiring independent research & analysis. The case studies will be fairly complex and have no single, finite solution.

UNDERSTANDING WATER AND ENERGY SYSTEMS FOR CIVIL AND ENVIRONMENTAL ENGINEERS

We believe that understanding water resources and energy systems are two crucial foundation areas for civil and environmental engineers. In this paper we focus on understanding energy, since fortunately water systems are already part of the modern civil engineering curricula. Energy is a critical nutrient of life in nature and an indispensable ingredient for the progress of civilization. Energy is the one critical physical resource that allows the production, assembly and distribution of the entire infrastructure we rely upon as a society. Our current civilization and its future evolution are therefore inseparable from access to plentiful and cheap energy supplies. Understandably, the production and use of energy also generate some unavoidable negative effects, both to the humans and to the environment that we have to deal with.

The USA is presently not self-sufficient in energy production. Nor can it be, if it continues to rely on petroleum as a primary source of energy. This is a serious concern for the US and for all countries with a heavy demand for energy. It should be a reason for vigorous government and industry activity aimed at achieving energy self-sufficiency and arriving at a timely solution to this nagging and dangerous problem. The role of educators is to prepare students to face these challenges.

Despite this overwhelming importance of energy related problems, Civil and Environmental Engineering programs, from East to West Coast [8,9], virtually ignore offering a fundamental course for engineers that would provide the basic understanding of energy related issues. Students, who become future civil and environmental engineers, must understand well the energy needs of the society, the sources to provide energy, the technologies to obtain it, the methods of its distribution and transportation, as well as all the consequences and risks to the society in a positive and negative sense.

For example, the essence and nature of the main source of primary energy, that is, hydrocarbons, from coals to oils to natural gas, has to be understood well. The first issue is the uneven geographical distribution of hydrocarbon sources that results in large flows of semi-hazardous materials from source to user. A second and currently much debated issue arises from the fact that the energy contained in all hydrocarbons is released by burning the hydrocarbon with air. This process releases carbon dioxide and some minor but noxious amounts of several kinds of oxides of nitrogen. The release of carbon dioxide, the principal component of the Green House Gases (called GHGs) that are present in the exhaust gases of hydrocarbon combustion, is the one issue, which will persist. It is clear that carbon dioxide concentrations are increasing in the atmosphere and they will continue to do so as long as we burn hydrocarbons to obtain massive amounts of energy.

Thus, there is an important role to play for future engineers and their educators. To understand how to deal with the realities that are consequent on the use of hydrocarbons for energy production, we must take a closer look at energy uses and resources. Then we need to examine the alternatives. This will lead to consideration of the possibility of implementing hydrocarbon-free energy sources. Technologies exist to extract power from wind, earth, sun and water [10] but it has to be examined and discussed, whether any of these sources are economically, ecologically, or practically viable to supply the present and expected future energy needs in a hydrocarbon-free energy scenario.

The unavoidable emission of GHGs from hydrocarbon motor fuels is the attraction for switching to a new portable fuel, hydrogen. This can be used to operate on-board hydrogen fuel cells to generate on-board electricity, that in turn will power the vehicle. But the role and consequences of introducing completely new fuels, such as hydrogen cells, has to be well understood. The appearance of fleets of private automobiles fueled by hydrogen may introduce numerous new problems, such as the threat of explosions after collision, and from leaks in general; increased humidity in heavy traffic (hydrogen fuel cells emit water); exhaust-generated fogs on highways in certain climatic conditions, etc.

There is an overwhelming list of topics that future engineers should be familiar with. Building a new program in a discipline provides a chance to introduce such a course on *Understanding Energy* that would form the basics of further study in the discipline. A proposed outline of such course, based on a 14-week schedule, is presented below [11]:

1) Energy: The Food of Civilizations – Introduction to the Course
2) Problems with Energy Use
3) Energy Consumption
4) Conventional Sources of Energy and Consequences of Their Use
5) Environmental Aspects of Energy Technologies
6) Political and Technical Solutions to Reduce Energy Demand
7) Technical and Political Solutions to Increase Energy Supply
8) Alternative Fuels and New Technologies
9) Long-Term Approach #1: The Hydrogen Option
10) Long-Term Approach #2: Nuclear Power
11) Transportation and Distribution of Energy
12) Risk Management Considerations and Social Issues
13) Health and Safety Issues
14) Looking into the Future

ELECTRICAL & MECHANICAL FOUNDATIONS FOR BIOENGINEERING

The scope of Bioengineering is vast, and it is not possible to predict exactly in what area of Bioengineering our future graduates will work. Therefore, the method of teaching the Foundations should be flexible. In principle, on the engineering side (as opposed to biology), there are two basic components for foundations of every Bioengineering program [12]: electrical component and mechanical component. In this paper, we primarily deal with mechanical foundations, mentioning electrical engineering briefly at the end of this section and leaving the detailed discussion of electrical engineering foundations for a later date.

It is envisioned that a 14-week (one-semester) course, comprising 4 hours of lectures and 2 hours of solving problems and laboratory exposure will be designed. Such a course will consist of elements of five parts. Each of these parts constitutes a separate course in the Mechanical Engineering curriculum, however, we will include in our course of Mechanical Foundations elements of each and combine them in one entity.

We feel that Mechanical Foundations should contain the following necessary elements:

1) Material Science
2) Statics
3) Dynamics
4) Strength of Materials
5) Mechanical Engineering Design

Material Science part should expose students to the properties and the structure of engineering materials, such as metals, various kinds of plastics, wood. It will be shown in what different circumstances and in what kinds of instruments and machines we use these materials, and why.

Statics part will introduce students to the notion of vectorial presentation and manipulation of forces, the notion of equilibrium of force and moment systems, and the analysis of mechanisms based on the Statics principles.

Dynamics part will contain elements of kinematics of particles, and kinetics of particles, including equations of motion, work, potential and kinetic energy, and impulse and momentum.

Strength of Materials portion will extend the knowledge gained in the previous three parts. It will introduce the concept of stress and strain, the analysis of one-dimensional axial loading, two-dimensional transformation of stresses and strains and the application to torsion of shafts, and to bending of beams. A short exposition of energy methods, or the stability of columns may be added.

The ultimate goal of the course is to show how the four earlier parts fit into the Mechanical Engineering design and analysis of structures [13]. The design examples will be chosen carefully in order to illustrate the importance of the knowledge earned so far in the design of structures, such as medical instruments. Topics on failure prevention, elements used in design, such as gears, springs and various fasteners, will be discussed. There is a vast possibility here limited only by the time constrains.

The course on Mechanical Foundations will be integrated with other courses, so that the presented material not only is combined smoothly, but also is related to other courses of the program.

Discussion of Electrical Foundations is a bit more complicated, since in addition to the true foundations, several other EE related courses must be taken by students specializing in bioengineering. Such courses normally include: scientific instrumentation, signal processing, system analysis, and others. These higher level courses can be included in a core curriculum for bioengineering, so their discussion may be deferred to when this specialization is developed.

Regarding Fundamentals, the following three levels of knowledge can be considered:

1) *Fundamentals of Electrical Engineering.* Introduction to electrical engineering. Basic circuit and systems concepts. Mathematical models of components. Kirchoff's laws. Resistors, sources, capacitors, inductors, and operational amplifiers. Solution of first and second order linear differential equations associated with basic circuit forms. Steady state sinusoidal excitation and phasors.
2) *Circuit Theory.* Electric circuit theory. Analysis of circuits with sinusoidal signals. Phasors, system functions, and complex frequency. Frequency response. Computer analysis of electrical circuits. Power and energy. Two port network theory. Laboratory in basic electrical engineering topics.
3) *Continuous Time Linear Systems.* Introduction to continuous time signal analysis. Basic signals including impulses, pulses, and unit steps. Periodic signals. Convolution of signals. Fourier series and transforms in discrete and continuous time. Computer laboratory.

FOUNDATIONS FOR A SOFTWARE ENGINEERING PROGRAM

The need for well-prepared software engineers in Southwest Florida is overwhelming for two reasons. First, in a recent survey [14] we identified a significant number of service industries in the region, whose business is strictly dependent and relying on software. Those industries and companies include: e-commerce (FindWhat.com [15]), transportation (Harvey Software [16]), hospitality management (GuestClick [17]), health care (NCH Healthcare System [18]), financial services (ASG Software Solutions [19]), technology (Robotics Workspace Technologies [20]), and others. Secondly, as previously indicated in [1], the region needs to change the structure of its workforce and employment base, to increase competitiveness by increasing the number of knowledge-based jobs and focusing on innovative activities that generate certain positive employment patterns. All this is driven by software technologies. Since computer software became central to all innovation processes, the vision is to focus on innovative software technologies and software engineering to foster innovation through software and initiate the formation of a "technology cluster" [21].

In creating an undergraduate Software Engineering program based on need, several important factors have to be taken into account, such as: educational objectives, student base, faculty qualifications, curriculum, access to labs and other facilities, accreditation, costs, etc. In this paper, we only deal with the curriculum issues. In this respect, it is important to realize that a strictly related undergraduate program, Computer Science, already exists, which could form a strong basis for a new Software Engineering Program. The idea is that to minimize initial costs of starting a new undergraduate program, an existing Computer Science program could be reshaped and complemented by certain additional courses and requirements to meet the standards of the profession as prescribed by the IEEE/ACM Joint Task Force on Computing Curricula [22].

In this view, we looked at over a dozen existing undergraduate software engineering programs in the U.S., to see the similarities and compare other important factors that would help us develop our own solid curriculum. It has been determined that having a good existing Computer Science or Computer Engineering program is a definite advantage when creating a software engineering curriculum. First, a related program provides a necessary base, regarding resources and faculty, for a prospective new program, and, second, a new curriculum can be developed by applying a minimal number of modifications to the existing one. One such recently created undergraduate Software Engineering program, at Embry-Riddle Aeronautical University [23], has been studied in significant detail and helped us determine the criteria to modify and expand Computer Science curriculum, to make it compliant with the requirements for both the existing CSc program and the prospective Software Engineering program.

It has been determined that, under the circumstances, the optimal path for Software Engineering should be composed of two primary steps:

1) Modification of the existing CSc program to make it (a) compliant with current ABET accreditation criteria [24] and (b) suitable for hosting a concentration in Software Engineering (Fall 2004)
2) Development of a B.Sc. in Software Engineering, by adopting a suitably modified CSc curriculum, as soon as the new School of Engineering begins admitting students (Fall 2005).

The proposed degree requirements for BS in Computer Science, and minor enhancements for concentration in Software Engineering (marked by an asterisk) [25] are outlined below, in terms of credit hours:

General Education (40 hrs)
- Communication 6 hrs
- Social Sciences 6 hrs
- Humanities 9 hrs
- Natural Sciences 12 hrs
- Mathematics 7 hrs

CSc Prerequisites (14 hrs)
- Introduction to Computer Science
- Discrete Math
- Calculus I & II
- [includes General Physics I/II listed in Nat. Sci.]

CSc Major (42 hrs)
- Introduction to Programming
- Programming II
- Object-Oriented Programming
- Data Structures
- Operating Systems
- Digital Systems
- Computer Organization and Assembly Prog.
- Computer Architecture
- Software Engineering
- Computer Networks
- Database Concepts and Administration
- Algorithms
- Senior Software Engineering Project
- University Colloquium

CSc Electives (15 hrs)
- Computer Graphics
- Simulation and Modeling *
- Data Acquisition and Control Systems *
- Professional Writing *
- Advanced Business Programming
- Independent Study

Approved General Electives (9 hrs)

CONCLUSION

This paper discussed recommended strategies for designing new engineering curricula at the newest university in Florida's public education system. The paper introduced an approach or philosophy called Homegrown Engineering [3] that satisfies regional needs while maintaining a global perspective. Rather than replicating existing (traditional) engineering programs in the State of Florida, the paper proposed targeted engineering programs that meet the real economic-development needs of the Southwest Florida region with a socio-economical World view; for instance, a civil-environmental engineering program with water-resources, energy and sustainable development foci; an engineering management with a construction and service-manufacturing foci as well as a bioengineering program with a biomechanics/biomedical focus that addresses present and future needs and that links with the new biotechnology program at FGCU. Also, the paper stressed the need for a software engineering program---including quality assurance and networking emphases---while keeping the fundamentals of engineering practice.

The authors explained who homegrown (regional, customized, highly adaptive) engineering programs can help the local industry react quickly to global competitive challenges—including engineering off-shoring and outsourcing. There are numerous benefits to having engineering faculty researchers available to the agricultural, construction, health, hospitality, information-technology, real-estate and clean-manufacturing industries in the region.

As mentioned earlier, an important curriculum-design consideration is meeting FGCU sustainability mission. Fortunately, industry leaders---such as, the Accreditation Board for Engineering and Technology (ABET) and Industry Advisory Council (IAC) ---have indicated that sustainable development is a prevailing economic, environmental, and social concern in engineering education [4]. Succinctly, engineering students at FGCU must be prepared to design for sustainability. The curricular design is now in its initial phase of development. The College of Business is recruiting a new director for the program, as well as its faculty. The authors have advocated a few ideas to serve as "food-for-thought" during the program development process.

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