2006-2554: THE DEVELOPMENT OF A CURRICULUM TO INSTILL ENGINEERING LEADERSHIP & MANAGEMENT SKILLS IN UNDERGRADUATE STUDENTS

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The Development of a Curriculum to Instill Engineering Leadership & Management Skills in Undergraduate Students

Abstract

A report published by the National Academy of Engineering entitled "Educating the Engineer of 2020: Adapting Engineering Education to the New Century", has identified the necessity to instill leadership and management skills in future engineering graduates. Therefore, the need to teach leadership and management skills within engineering programs is becoming more prevalent. Currently, the majority of engineers that graduate with a bachelor degree have never worked on developing these skills during their academic programs. Considering the gap in covering leadership and management topics in Engineering Education, curriculum reform is needed to adequately prepare students. Thus, this paper discusses the development of a minor program of specialty in Engineering Leadership & Management that can be pursued by all engineering and computer science majors while completing a BS degree.

Keywords: Leadership, Management, Engineering Education, and Curriculum Reform.

Introduction

Engineering education in the United States is currently undergoing a crucial period of awareness where the necessity to reform academic program curriculum is becoming more evident in order to maintain technological leadership and competitiveness of the US in a global economy. The following table shows the "Occupational employment projections to 2012", published in the February 2004 Monthly Labor Review.

Employment by occupation, 2002 and projected 2012 [Numbers in thousands of jobs]

2000 Standard Occupation Classification		Employment				Change		Total job openings due to growth and net replacements, 2002-12 [1]
		Number		% distribution				
Title	Code	2002	2012	2002	2012	Number	Percent	
Aerospace eng.	17-2011	78	74	0.1	0.0	-4	-5.2	19
Civil eng.	17-2051	228	246	0.2	0.1	18	8.0	55
Computer eng.	17-2061	74	78	0.1	0.0	5	6.1	17
Electrical/ electronics eng.	17-2070	292	309	0.2	0.2	17	5.7	74
Environmental eng.	17-2081	47	65	0.0	0.0	18	38.2	26
Industrial eng.	17-2110	194	213	0.1	0.1	20	10.1	67

Employment by occupation, 2002 and projected 2012 [Numbers in thousands of jobs]								
2000 Standard Occupation Classification		Employment				Change		Total job openings due to growth and net replacements, 2002-12 (1)
		Number		% distribution				
Title	Code	2002	2012	2002	2012	Number	Percent	
Mechanical eng.	17-2141	215	225	0.1	0.1	10	4.8	69
Engineering managers	11-9041	212	**231**	0.1	0.1	20	9.2	**62**

(1) Total job openings represent the sum of employment increases and net replacements. If employment change is negative, job openings due to growth are zero and total job openings equal net replacements.

Findings of "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" report reveal that it is vital to equip students with knowledge, skills, and experiences in the area of leadership and management. Leadership tends to promote more equifinal approaches that seek effectiveness which complements efficiency. Management tends to promote organizational behavior approaches that enable high levels of order with an ultimate eye on efficiency. The issue with promoting leadership and management is that organizations must have both; 1) Leadership to provide necessary fluidity and fuller engagement of human dimensions for maximum effectiveness, and 2) Management to provide needed consistency, structure, and synchronization. A variety of leadership and management topics can be introduced to engineering students by using experiential learning activities during the course of study. Engineering students can explore various areas such as leadership, communication, negotiation process, global awareness, and workforce diversity. "Experiential learning occurs as a person engages in an activity, looks back at the activity critically, abstracts some useful insight from the analysis, and puts the result to work in another situation. It is an inductive process, proceeding from observation rather than from a priori "truth". The effectiveness of experiential learning is based on the fact that nothing is more relevant to us than our own reactions to, observations about, and understanding of an activity or idea"[1].

The Industrial Engineering and Management Systems (IEMS) department at the University of Central Florida (UCF) has a National Science Foundation supported research and development program aimed at producing a model for curriculum enhancements and instructional strategies that will increase student learning and preparation for future careers in Industrial Engineering, Re-engineering the Industrial Engineering Program. As a part of this activity, the department has developed an Engineering Leadership & Management Minor available to students majoring in various disciplines of engineering and computer science.

Literature Review

Development of academic programs that create leadership skills among engineering students is gaining increased interest in our country. In surveying the literature there are a variety of "leadership" programs on college campuses. For example, those that encourage students to

become leaders of campus activities; those that encourage entrepreneurial activities and those aimed at increasing the student's self-esteem, and self-confidence. Some examples include:

1. Pennsylvania State University offers a Leadership Minor with an emphasis on entrepreneurial development since 1995, and the Electrical Engineering department administers it[2]. "The program, which is open to all Penn State students, has many foci not usually found in undergraduate curricula including entrepreneurship, innovation, creativity, and leadership styles and development. Classes also explore public policy, ethics, and a host of business issues in the finance, marketing and investment areas"[3].

   Required Courses include: 18 Credit Hours

ENGR 408	Leadership Principles	2 hrs
ENGR 493	Leadership Laboratory Experience	1 hrs
ENGR 407	Technology-based Entrepreneurship	3 hrs
ENGR 409	Leadership in Organizations	3 hrs
ENGR 497B	Creativity, Innovation and Change	3 hrs
XXXX xxx	Leadership-Based Electives	6 hrs

2. Purdue University offers a certificate, an associate in science degree, and a bachelor degree in Leadership but not a minor. Organizational Leadership and Supervision (OLS) degrees provide a broad-based education for those desiring leadership roles in business, government, or industry. The Department of Organizational Leadership and Supervision is located in the Purdue School of Engineering and Technology, and is one of seven academic departments[4].

   The Certificate in International Leadership is appropriate for individuals who may have international supervisory leadership responsibilities and/or work with individuals from different countries. It is also appropriate for those students who wish to acquire knowledge, skills, and abilities to prepare for an overseas work assignment. The curriculum requirements include:

   Section I: Required Core Courses (15 hrs)

   - Leadership for a Global Work Force
   - Principles of International Management
   - Intercultural Communication
   - Lang six hours of a single foreign language

   Section II: International Experience and/or Additional Language Electives (3-7 hrs)

   - Intern up to 3 credit hours-approved overseas internships
   - Study up to 6 credit hours-approved study-abroad program
   - Lang up to 4 additional hours of the foreign language chosen in the core

Section III: Related International Electives (5-9 hrs). As students develop a certificate plan of study, they must accumulate the balance of their elective credits from one of the following four focus areas.

- Business and Economics focus
- Political focus
- Social and Cultural focus
- Area Studies focus

In addition, the Certificate in Leadership Studies equips students with the knowledge, skills, experiences, attitudes, perspectives, and tools necessary to understand the broad-based concepts associated with leadership in a variety of individual, organizational, and community settings in an ever changing, pluralistic, global society.

The curriculum requirements include:

Required Courses		18 Credit Hours
OLS 252	Human Behavior in Organizations	3 hrs
OLS 263	Ethical Decisions in Leadership	3 hrs
OLS 274	Applied Leadership	3 hrs
OLS 327	Leadership for a Global Workforce	3 hrs
OLS 390	Leadership Theories and Processes	3 hrs
XXX xxx	a 300 or 400 Elective course	3 hrs

The Associate in Science degree in Organizational Leadership and Supervision (OLS) requires:

Required Courses	61 Credit Hours
Organizational Leadership and Supervision	22 hrs
Applied Technology	18 hrs
Behavioral or Social Science	3 hrs
Communication	9 hrs
Mathematical Skills/Applications	9 hrs

The Bachelor in Science degree in Organizational Leadership and Supervision requires:

Required Courses	124 Credit Hours
Organizational Leadership and Supervision	43 hrs
Applied Technology	24 hrs
Behavioral or Social Science	6 hrs
Communication	18 hrs
Mathematical and Science	16 hrs
Humanities	6 hrs

Electives 11 hrs

3. Several engineering programs offer leadership development thru partnership with student activity sectors as a means of targeting talented first-year students and integrating them with the academic and co-curricular aspects of college life. As an example, the LEAD Scholars Program (LSP) was established at the University of Central Florida in 1995. The LSP specifically assists in reaching the university's goals of offering the best undergraduate education available in Florida, becoming a more inclusive and diverse institution, and becoming America's leading partnership university.

   UCF is committed to accenting the individual and excellence as well as educating the whole person and producing future leaders who exhibit leadership, academic excellence, and service. The Lead Scholars Program exists within this context and is dedicated to providing high-quality educational experiences and leadership opportunities to prepare students for positions of leadership both inside and outside the UCF community[5].

It is evident that, Leadership Studies at various institutions equip students with a strong mixture of interdisciplinary perspectives that enrich the learning environments. Topics such as Organizational Behavior, Ethics, Leadership Theory, Business in a Global Environment, Intercultural Communication, Occupational Safety and Health, Employment Law, Women Leadership, Finance and Economics, and even religious focus may be covered.

Engineering Leadership & Management Minor at the University of Central Florida

The curriculum emphasis of this academic program is structured to allow students to obtain a Minor Degree of Specialty in Engineering Leadership & Management. This option will be available to all engineering and computer science students as well majors with a minimum GPA of 3.0. This minor can be earned with 18 credit hours of coursework. This minor focuses on providing courses with the basic understanding of project engineering, engineering administrative, team effectiveness, and financial engineering coupled with a Leadership Development Institute experience to engineering and computer science students.

This Leadership Development Institute experience will be offered in two modules during the Fall and Spring semesters with the seminar classes meeting weekly. These classes will be offered during the Junior and Senior years of student classification starting in the Fall 2006 semester. The planned topic areas of concentration include: 1) Leadership foundation concepts and theories, 2) Communication, Negotiation, Conflict Management, and Global Awareness as well as other leadership principles.

The goals of the Leadership Development Institute include:

- Provide students with a baseline of knowledge for exploring and understanding engineering leadership and management challenges in engineering environments; i.e. solutions, tools, and approaches in today's engineering professional and multi-cultural/multi-national environments.
- Begin student understanding and formulation of ethical engineering leadership and management practice.

- Assist students gain self-understanding and self-confidence needed for effective engineering leadership and management practice.
- Apply critical/creative thinking skills to the study and practice of leadership and management.
- Develop systems thinking as it relates to engineering leadership and management practice.
- Enable students to quantify relations between dynamics and processes involved in organizational management and behavior to enable or support effective engineering leadership and management.
- Provide students with the opportunity to learn and practice effective oral and written communication skills.
- Further explore and enable the application of models and tools introduced during IEMS and CECS curricula; particularly as they relate to systematic leadership and management behavior and utilization/application.
- Provide experimental and project exercises that will permit the student to experiment with and evaluate various tools and processes involved with work team design, implementation, and utilization.
- Introduce and examine historical, philosophical and theoretical perspectives of work teams.
- Show students the interrelationships and connections of professional engineering leadership and management to other engineering courses and technical systems.
- Introduce and/or widen student understanding of the contributions in the various engineering disciplines.
- Examine personal values and academic plans toward future goals.
- Provide students with operational, practical understanding of communications as a fundamental process in engineering management and leadership practice in engineering environments.
- Enable and assist students in developing the skills needed to establish presence and influence.
- Assist students in gaining self-understanding and self-confidence needed for effective leadership and engineering management practice.

The UCF IEMS Leadership Development Institute will provide a holistic, meta-cognitive learning and developmental experience designed to strengthen the student's mastery of leadership and management principles and practices. A holistic curriculum to emphasize leadership development has been designed to cover multi-faceted topics such as managing diversity at the workplace, leadership principles, ethical engineering practices, effective communication skills, conflict management, negotiation skills, team effectiveness, and global awareness. Also, recent research performed by the IEMS department at UCF on using the theory of meta-cognitive models to develop instructional strategies concludes that the current method of organizing information in engineering courses (i.e. which is bottom-up should be reversed to a top-down approach). In other words, begin engineering courses by introducing the products of the discipline or the high level generalities and abstractions only later to be followed by the mechanics and procedures for implementation. This strategy will provide a greater meaningfulness and comprehension as well as facilitate the acquisition and retention of curriculum content compared to the traditional approach of engineering education. Modeled upon assessment center methodology, students will be placed in structured experiential role-plays so trained assessors can assess their performance. These assessors will also be trained to provide developmental feedback. As currently envisioned, students will receive 2-3 structured

experiences each semester. These experiences will include role-plays assessing them in student roles, in young professional roles, and various engineering roles.

UCF Engineering Leadership: Management Curriculum

Academic Program: Students will complete four required courses as described below. Additionally, students will complete two laboratories/Capstone of seven-credit hour in Engineering Leadership & Management. Participation in this minor program of specialty will provide students with an understanding of engineering management principles, practices, tools, and techniques currently used in the workplace. Also, this program will provide exposure to leadership issues and management approaches prevalent in the engineering profession.

Required Courses: Students will be required to take four courses: Engineering Economy (2 credit hours), Financial Engineering (3 credit hours), Project Engineering and Work Team Design (3 credit hours), and Engineering Administration (3 credit hours). Additionally, students will complete the Engineering Leadership & Management Experimental Laboratory courses I-II/Capstone (7 credit hours total). It is anticipated that students will complete this program in three semesters, earning a total of 18 hours.

Administration:

a. This program will be administered under the auspices of the Industrial Engineering and Management Systems Department in accordance with applicable policy and regulation.
b. To avoid excess hour issues, students will be able to dual count student credit hours of the courses toward both major and minor.
c. No new faculty lines will be required to support this minor.

Required Courses (18 Credit Hours)

EGN 3613	Engineering Economy	2 hrs
EIN 3354	Financial Engineering	3 hrs
EGN 4624	Engineering Administration	3 hrs
EIN 4392	Project Engineering and Work Team Design	3 hrs
EIN 4001	Engineering Leadership & Mgt Lab I	3 hrs
EIN 4002	Engineering Leadership & Mgt Lab II-Capstone	4 hrs

Experimental Laboratory I, focuses on understanding engineering management and leadership principles, practices, tools, and techniques as they pertain to engineering venues. It will initiate and facilitate the development of sound ethical engineering practices and will help develop a baseline for the study of engineering leadership and management principles, practices, and techniques. Some of the topics covered in this lab include:

- Definitions of leadership and management
- The symbiotic and mutually supportive nature of leadership and management
- Unique challenges of leadership and management in engineering settings
- History of leadership and management thought as it pertains to engineering

- The relationship of leadership and management to engineering performance and effectiveness
- Leadership and management skills as they relate to project management
- Leadership and management skills and entrepreneurship
- A systems perspective of leadership and management
- The engineering ethic and practice of leadership and management

Experimental Laboratory II- Capstone, focuses on the development of effective communications and negotiation skills, and the presence needed to succeed in a global environment. It will provide students the ability to influence others, avoid conflict, manage change, and bring win-win situations in a multicultural work environment is the truthful definition of a leader in the XXI century. Some of the topics covered in this lab-capstone include:

- Defining and Exploring the Constituent Elements of Presence
- The Hampton Communications Model
- Communication Challenges of the Engineering Environment
- Effective Communication Strategies in Engineering Settings
- Using Basic and Advanced Communication skills to enhance productive leadership and management
- Coaching and Mentoring Communication Skills
- Electronic Communications – use as effective leadership and management tool
- The Internationalization of Engineering; how international businesses conduct engineering practice
- Engineering Ethics in a Global Context
- Defining Negotiation and Conflict Management
- The Negotiation Process
- The Conflict Management Process
- Contract and Project Negotiations
- Using Leadership and Management to effect conflict management and negotiation effectiveness
- Negotiations in the Employment Process
- Creating an Environment in which Negotiations and productive conflict thrive
- Transactional Analysis Model
- Global trends and cultural considerations in engineering that affect leadership and management practice
- Understanding NAFTA/CAFTA and its effects upon engineering practice
- Effectively leading and managing diversity in organizations

Evaluation and Assessment

A systematic approach to assess program success will be incorporated. The program assessment plan entails two parts: curriculum assessment, and student evaluation before and after program accomplishment.

Perry Model of Intellectual Development can not only help to evaluate the engineering degree, but also help to drive and improve the actual curriculum[6]. The tools to assess this degree consist of student interviews and written essays in order to identify the Perry Model level of the student (level 6 ideal for professionals); in addition, a scenario-based questionnaire is proposed to assess student's problem solving, management, and leadership skills. Also, the Ennis-Weir critical thinking essay test is recommended for this application. These tools can be administered to a group of students from the minor program and another control group of engineering students who are not enrolled in the program.

Conclusion

In order to maintain the superiority and competitiveness of the United States, the nation must be able to adequately educate and promote the development of needed skills in the future workforce. Former Oregon Governor Barbara Roberts said: "I began to understand that I could influence people, that I could change people's minds. Maybe the first sign that you have a leadership skill is that you can move others… and I don't believe you can be a real leader without passion. I also don't believe you can be a real leader without risk taking"[7]. Considering the rapid advances in technology that are occurring in today's marketplace it is dismal to see that engineering curriculums look similar to those of twenty years ago. Engineering curriculums should provide the education necessary to support nation's security needs and interest.

Successful managers must understand current technology to make the appropriate decisions, but successful engineers are not adequately educated and trained to become leaders and manage the workforce[8]. Therefore, the education gap identified between engineering curriculums and industry management and leadership skills supports the need for curriculum reform. "The Engineer 2020" report has identified the need for (good communicators, mastering the principles of good business and management, understanding the principles of leadership, possessing high ethical standards, strong sense of professionalism, and possess a complex attribute described as dynamic, agile, resilience, and flexible)[9]. Thus, an Engineering Leadership & Management Minor has been developed at UCF to respond to meeting the educational needs of the engineer of 2020.

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