AC 2011-2786: AN EDUCATIONAL SYSTEMS ENGINEERING MODEL FOR LEADERSHIP ENGINEERING

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An Educational Systems Engineering Model
For Leadership Engineering

Abstract

Innovative pedagogy such as experiential education at graduate level has shown significant impact on learning and career development. Implementations of these techniques are especially difficult in an engineering academic environment. This paper introduces efforts at the Research Institute for Manufacturing and Engineering Systems (RIMES) at UTEP to define, create, and implement an academic model fostering systems thinking through experiential or practice-based education by allowing team work on application of principles being learned. The paper presents how Research, Technology Development, and Academic programs are brought together to foster multi-disciplinary work and end-to-end systems thinking into a self-sustaining infrastructure closing the gap between engineering education, academic research, and industry applied research needs. The paper details our approach to experiential education leading to systems thinking development by using multidisciplinary teams assigned by professors to work on industry-led projects in the classroom that counts for a significant percentage of the final grade. It also explains how industry is engaged through outside-class projects jointly supervised by industry leaders and professors; these inside and outside class room experiences become the primary mechanisms to develop the soft engineering skills required from engineering graduates. While we encourage students and faculty internships with industry, we also schedule "industry practitioners" for project reviews, seminars, workshops, and guest lecturers. Program objectives and outcomes follow ABET guidelines and have been jointly defined with industry partners to measure program effectiveness and progress through its implementation.

Finally we will discuss the business model for our approach and how we manage the industry relationships, client-service provider interactions, and the University's commitment to contractual deliverables in developmental projects and industry sponsored research.

Key words: *Systems Engineering Education, Multidisciplinary Engineering, Systems Engineering, Engineering Leadership, Systems Engineering Research*

1. Introduction and Motivation

Numerous studies and Engineering Research papers have been conducted pointing out the need to align engineering education to close the existing gaps between academic engineering programs, industry needs, and the increasing presence of the global engineer. The ever evolving complexity of man-made systems and the lack of end-to-end systems thinking for the design and development of these systems have spurred a lot of debate on current engineering academic programs and the need to change engineering education so as to have better fitted engineers to industry needs and to maintain our competitive advantage in a global service based economy.[16, 11, 29]

The Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering commissioned the National Research Council of the National Academies to examine the role that Systems Engineering can play during the defense acquisition life cycle and address the root cause of program failure during the early phase of the program. In some of its findings, the National Research council states: "*There is a need for an appropriate level of* ***SE talent*** *and leadership early in the program, with clear lines of accountability and authority. Senior* ***SE personnel*** *should be experienced in the product(s) domain, with strong skills in architecture development, requirements management, analysis, modeling and simulation, affordability analysis, and specialty engineering disciplines (e.g., reliability, maintainability, survivability, system security, and technology maturity management*"). It continues to state: "*. . . there are no longer enough experienced* ***systems engineers*** *to fill the positions in programs that need them, particularly within the government. As acquisition programs continue to evolve from individual systems to systems of systems, this shortage will only become more acute".*[3]

The National Academy of Engineering Report on the 21st Century Engineering Grand Challenges not only points out to the engineering challenges but also the Eco-systems nature of the challenges and thus the need to foster end-to-end Systems Thinking; "*. . . contemporary challenges from bio-medical devices to complex manufacturing designs to large systems of networked devices- increasingly require a systems perspective. This* ***drives a growing need to pursue collaborations with multidisciplinary teams of technical experts.*** *Important attributes for these teams include excellence in communications (with technical and public audiences), an ability to communicate using technology and an understanding of the complexities associated with a global market and social context*"**.**[18] These challenges being multi-disciplinary require the participation not only of specialty engineering but also of the social sciences, natural sciences, and business practices. Consequently, it is important to create educational programs to train engineers with not only an excellent understanding of the technologies involved but also to develop engineering leadership skills to lead multidisciplinary-teams to think on the overall solution. "*In every major global challenge, from the eradication of the endemic blight of poverty, to universal and effective healthcare, economic development, urbanization, security and global warming,* ***systems engineering*** *of the highest order is called for as it must encompass and harmonize social, political and economic systems, healthcare and nutrition issues, as well as the more traditional engineering systems that deal with water and energy supply, construction, infrastructures and production*".[29]

This multi-disciplinary evolution requires the establishment of cultures of entrepreneurships for rapid innovation and continuous evolution to adapt to self-learning "social networks". The early 1990's saw the creation of virtual environments for engineering design with distributed, multi-disciplinary teams which today are considered to be well established best practices for new technology/product development and design within industries. However, by the time engineering students graduate from Colleges and Universities they are disconnected from the real world since academia has not prepared them for this multi-disciplinary approach.[5, 11, 30] In addition, 21st Century engineers are not only faced with this multi-disciplinary lack of skills but also with the complexity of systems where traditional decomposition analysis and problem solving for the design of systems are not sufficient for the multitude of technological, ethical, regulatory, and environmental issues that need to be taken into account for the design, deployment, and Life Cycle Management of the 21st century systems, thus shifting from traditional design toward innovative ideas to include all of these areas[25, 24, 19]; a recent report by UNESCO on engineering around the world suggest that engineering education might benefit from less formulaic and more problem-based, project-based, and just-in-time approaches in order that the next generation of engineers can rise to the challenges and opportunities they are inheriting”.[28]

It has also been shown that the most prominent engineers within industry have developed specific soft skills required to communicate, empower, and lead teams to the successful definition and completion of complex innovative products; as an example, a study carried out at NASA shows that out of 38 skills, 36 are directly related to communications, leadership, attitudes, and systems thinking. While only 2 of the skills are the "hard skills" dealing with technical acumen. The data yielded 38 key characteristics or behaviors which were grouped into five categories: 1) leadership, 2) attitudes, 3) communication skills, 4) systems thinking, and 5) systems acumen; the results clearly indicate the soft skills above and beyond the technical “acumen” are clearly what set the best NASA engineers apart.[31]

This paper concentrates on the Systems Engineering (SE) graduate programs developed in the College of Engineering (COE) at the University of Texas at El Paso; similar efforts on redefinition of curricula at the undergraduate level are also being conducted and the reader is referred to Schoephoerster and Golding[21], for details on new undergraduate programs in Leadership Engineering.

Section 2 discusses the major premises included in the design of the Master of Science in Systems Engineering (MSSE) to address the engineering education issues mentioned above; Section 3 discusses the business model adopted for initial deployment, sustainment and future evolution of the program; Section 4 presents outcomes and successes of the program; Section 5 presents challenges and lessons learned through the design and actual deployment of the program and finally in Section 6 we discuss future work and the main conclusions of the effort.

2. MSSE Program Elements

During the initial stages of the Systems Engineering program at UTEP, an ad-hoc committee, consisting of representatives from different engineering disciplines and industries, was created. The committee was formed to address many of the issues presented in section one; an early decision was made to take a systemic approach following systems engineering practices[10] to ensure alignment of the program with engineering educational needs and with industry needs as expressed by industry participants.

The plan consisted of four (4) different phases: Discovery, Strategic, Deployment, and the Operations phase. The different activities and objective of each of the phases is explained below.

2.1. Discovery

During this phase the committee concentrated on:

- A common understanding of the needs and importance of having a program to train engineers not only technically competent but also who are leaders, innovators, and entrepreneurs.
- Understanding the current available capabilities at UTEP <u>(in the region)</u> by gathering data about:
    - Industry needs
    - Programs Offered
    - Financial Models
    - Course Inventory

We also carried out research to understand current programs implemented throughout the states and abroad; as a result several universities and industries were invited to respond to a questionnaire, designed by the committee, about their experience on key success factors and major challenges and roadblocks encountered during the implementation of their programs.

2.2. Strategy

The main intention during this phase is to ensure alignment with the COE Objectives, analysis of programs offered by other universities, program objectives, Targeted audience, sources of funding, and advisory board considerations. The output of this phase was a formal strategy/vision recommendation presented to the Dean's office for internal approval and to move ahead with the process for approvals by the University of Texas system and the Texas Coordinating Board for actual implementation of the program.

The main objectives of the MSSE program follow INCOSE guidelines[11] and were then defined as:

- To educate systems engineers, researchers, and educators who will address the cross-disciplinary engineering needs of the 21st century
- To educate professionals who will not only be technically competent across interdisciplinary emerging technologies but also address and adapt to changes and challenges associated with the increasing complexity of systems
- To engage engineers from different fields in the application of cross-disciplinary processes and models to resolve problems
- To develop the necessary communication skills to engage with customers and agree on goals in complex systems development
- To train and educate systems educators to respond to the global economy and to work in international environments

2.3. MSSE Deployment

This phase included the process needed to obtain approvals within the University of Texas System and the State of Texas Coordinating Board approval (THCB approval) including curricula and lines of research definition, industry support, government grants, multi-department participation, and program offerings. At this time we needed to get commitments from faculty on actual definition of the program, including program outcome objectives, course syllabus with objectives, outcomes and assessment, curriculum development, financial plans, etc. Thus it was important to analyze all the possible options, understand the audience, and possible sources of short, medium, and long term sustainability and funding rather than looking at short term quick hits. At this phase, there was a need to look into ways of accelerating internal trials and getting actual funding support from the COE, industry, and/or government agencies; a decision was made to start with a Graduate Certificate in Systems Engineering (GCSE), with the second educational option already in place being the Interdisciplinary Masters in Engineering with a concentration in Systems Engineering. These two options provided the forum for the development of the core Systems Engineering program. These early trials allowed us to have indicators of students' interest, industry acceptance and commitments, and actual response of interested faculty. During the internal trial phase we had students registered into the program from Electrical and Computer Engineering department since they accepted the initial course offerings as technical electives for the Masters program in ECE; as the program gained acceptance and recognition participation from other engineering disciplines and industry practitioners increased.

Several existing Systems Engineering programs at major US universities were analyzed and the committee decided to follow the guidelines of the INCOSE Reference Curriculum for Graduate Programs in Systems Engineering.[12, 26] The Systems Engineering Centric program consists of four Systems Engineering Core Courses (12 Semester hours), a Project Practicum with industry, three Systems Engineering prescribed advanced courses (9 Semester hours) and two electives (6 Semester hours). Table 1 below shows the Systems Engineering Centric Curriculum.

In addition, the program also allows concentrations in Electrical and Computer Engineering, Computer Science, Industrial Engineering, Manufacturing Engineering and Business Administration where the students have prescribed electives (9 credit hours) in each of these fields; the prescribed electives in these concentrations are a substitute to the SE Specialty courses in the SE centric program. Detailed curriculum for all of these concentrations can be found at http://rimes.utep.edu and at http://imse.utep.edu.

Table 1. Systems Engineering Centric Curriculum

MSSE COURSES	TOTAL CREDIT HOURS (SCH)	TITLE OF SE COURSE
LEVELING COURSES	0	• Engineering Probability • Engineering Economy • Numerical Analysis
CORE COURSES	12	• SE Fundamentals • SE Requirements Engineering • SE Management • SE Integration, Verification & Validation
INDUSTRY PRACTICE	3	• SE Project Practicum
PRESCRIBED ADVANCED COURSES	9	**REQUIRED**: • SE Architectures • SE Modeling & Simulation Plus 1 course from the following: • SE Processes • Decision & Risk Analysis or • Quality Engineering or • Computer Aided Design
FREE ELECTIVES	6	Any 2 courses from the following: **ENGINEERING:** • Reliability & Maintainability • Design for Manufacturability • Advanced Quality Control **MANAGEMENT:** • Global Management • International Strategic Management • Concepts of Production Management **LEADERSHIP:** • Pathways to Leadership in Engineering • Entrepreneurship in Engineering

If we were going to foster multi-disciplinary work and end-to-end systems thinking we needed to develop the right pedagogy that would foster systems thinking in our students. We identified two primary approaches: One is our strong belief in experiential education and active learning, which has been shown to develop systems thinking in engineers[13, 14]. This principle demands cooperative and interdependent learning, respect for diverse talent, and ways of learning.[2, 27]

The second principle is the primacy of the students and their development. This includes continuous encouragement of contact and interaction between students and faculty and among students themselves. All assignments and tasks, even the strategic use of office space, are designed to encourage and facilitate this interaction. This approach has developed reciprocity and cooperation among students and engenders a sense of co-responsibility for their own education. Assignments and tasks are never discussed in a vacuum; discussions include the contextual environment and the concepts being developed or applied.

Thus, the working premises of the MSSE program include team work, creativity and innovation, a significant amount of experiential learning through real life applications in an industrial setting, and an opportunity for students to develop a set of soft skills via strong collaborative linkages and supervision of industry partners. Thus, innovative pedagogy such as Project Based Learning (PBL) along with practice based experiential learning environment promotes soft skills for tomorrow's engineers.

Each of the SE courses has been developed to include the educational challenges and follow ABET requirements for the skills that go beyond technical knowledge.[1]

- "An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"
- An ability to function on multi-disciplinary teams
- An understanding of professional and ethical responsibility
- An ability to communicate effectively
- The broad education necessary to understand the impact of solutions in a global and societal context
- Recognition of the need for, and an ability to engage in life-long learning
- Knowledge of contemporary issues
- An ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice

To achieve these objectives, in addition to regular lectures, all the courses have a strong component of student centered-learning through PBL in a team environment, team and individual assignments, and individual test. We have given high importance to team work and communications by allocating at least 30% of the final grade to the projects; these projects are jointly defined with industry partners, or by the team themselves which may want to work on a new idea and/or in projects internal to the university defined jointly with the faculty.

In each of the courses, students' teams have three project deliverables during the semester; to present progress on the projects, to develop professional technical reports which are supervised by the Professors, and in many instances evaluated by the industry partner. Experiential learning is included in the curriculum through the Project Practicum; the project Practicum is a mandatory industry based practice where the students are assigned full-time on-site to work in teams on an actual company project usually during the summer time; with the experience gained during the in-class PBL projects the students are expected to prepare briefings for technical leaders and executives in the sponsoring company in addition to the creation of written internal memorandum or technical reports within the company. We are trying to mirror the Medical School model by requiring about 500 hours of on-site industry practice; we consider the practice to be similar to a capstone project but the major difference being the actual experience in realistic environments where the students are exposed to the dynamics of leading, advocating, communicating, technical and non-technical issues, etc. in a multidisciplinary team.

This combination of industry practice and PBL approaches presented the most difficult challenges for the program implementation due to the very different financial models between academia and industry; details of the hybrid financial model are discussed in Section 3.

The Masters program also introduces mechanisms for other academic departments to develop graduate programs supported by academic-industry partnerships.

2.4. Operations

In order to create world-class Systems Engineering, it is mandatory to create a program that generates industry accepted and peer-reviewed research. It is a well accepted fact that the ever increasing system's complexity and innovation is based on knowledge sharing and collaborative behavior among different disciplines[20] and that corporations have been evolving their research more and more into market oriented research (applications research) to remain competitive. Thus, we wanted to also jointly define with participating industries their major interest in research so as to have well defined research areas. Having this alignment we could now enter into the applications research, developmental projects, technical assistance, and extension programs efforts needed by industry which in turn could also be used to support experiential learning for our students and new opportunities for faculty research; these opened the doors besides the traditional grants, scholarships, fellowships, etc.

We have evolved the Institute for Manufacturing and Materials Management (IM3) into the Research Institute for Manufacturing and Engineering Systems (RIMES) to research and promote the use and deployment of current and future emerging systems engineering methodologies and life cycle management of end-to-end enterprise systems, and to provide technical assistance to small and medium size enterprises (SME) as a vehicle to further engage academics and industry. This evolution was needed to transform the initial 1990's mission of IM3 for SMEs to optimize their operations into manageable supply chains to the new realities of the 21st century for end-to-end enterprise optimizing knowledge sharing and organizing knowledge workers, entrepreneurs, and technologies into manageable partners; see http://rimes.utep.edu for details.

RIMES has several mechanisms to apply its research expertise to the enterprise. At the same time, RIMES established strong links with academic graduate programs such as a Multi-disciplinary Master of Science in Engineering, a Graduate Certificate in Systems Engineering (GCSE), the Master of Science in Systems Engineering (MSSE), Master of Science in Industrial Engineering (MSIE), and a Master of Science in Manufacturing (MSMFG). RIMES also supports academic endeavors such as curriculum and course development at the graduate level.

In this regard RIMES serves as an overarching structure to support not only research in Systems Engineering but also to foster interdisciplinary research and academic programs.

RIMES is organized into three main areas: SE Research, Technical Assistance, and Extension Programs.

- **Research**:
    - Methods Processes and Technologies for Integrated Development
    - Systems Of Systems (SOS) Formal Requirements Methodologies
    - Model Based Systems Engineering (MBSE) & Modeling Languages
    - Next Generation Network Centric Systems
    - Trade-off studies
    - Lean/Enterprise SE
    - SOS Reliability (Prognostics, Resilience)
    - SOS Risk Analysis

- **Technical Assistance**

    The Institute has a strong capability to design and deliver technical assistance to small and medium size enterprises in industry. As part of the National Institute of Standards Manufacturing Extension Partnership (NIST MEP) RIMES has executed over 400 contracts to deliver assistance which includes Strategic Operations, Lean Enterprise Initiatives, Quality Management, Technology Diffusion, and Workforce Development. These services are delivered by practicing field engineers where we see each engagement as another opportunity to enhance the experiential learning opportunities for our students.

- **Extension Programs**

    This area includes Executive Courses and seminars offerings such us Enterprise Excellence Workshops, Lean Enterprise Training Workshops, Lean Six Sigma Black Belt Certification and Predictive Maintenance Workshops. See http://rimes.utep.edu for details

3. Sustaining Model Strategy

Our target students come from a region where 75% of families earn less than $20K income. A large percentage of our target students are the first in their family to attend college and 68% of them work to help support their families and academic careers. In an environment like this, having the resources for student's support and infrastructure buildup are key components of long term sustainability and thus the need to create new mechanisms to generate non-traditional sources of revenues to offer financial support to our student population.

Traditional funding mechanisms like government agencies grants, internships, fellowships, scholarships, and university-led extension or technical assistance programs, even though very important, are not sufficient to cover the financial expenses associated with the execution of the hybrid industry practice and PBL approach much less when most of the participants students require financial support. Thus it was clear to us from the very beginning that other non-traditional mechanisms were required for us to succeed. Early in the program's history, we turned to industry to get the necessary additional support taking advantage of several known industry needs:

- Industries' challenges and recognition of the need of Systems Engineers: SE growth of 45% in the market for the next 10 years.
- INCOSE 2020 Vision: ". . . experts anticipate that systems thinking and systems engineering will guide the way people think about solving problems in the next decade and systems engineering will become an established international "inter-disciplinary connector" or "meta-discipline" . . . In the future systems engineering will be used to address the significant social, economic, environmental and planning issues of the day"[11]
- Changing Demographics and SE retiring workforce
- Drastic reduction of industry R&D budgets and the trends to outsource some of the Research to universities
- Mostly Applied Research in SE

Currently, approximately 80% of student support comes from research and technical assistance projects with industries while the remaining 20% comes from grants and scholarships. We have learned to develop and use contractual win-win situations where our faculty and students deliver valuable work products to our industry partners. The contractual mechanisms in place have a strong customer-supplier (industry-academia) relationship with commitments to have qualified resources, to deliver on time and cost, and most importantly to manage the projects through the industry Project Manager (PM) and the university PI. Because we have gained the credibility and reputation for delivering as contracted, we do not need to appeal to altruistic reasoning, but merely rely on a sustainable business relationship. We also leverage some of this industry support as seed money for government research grants to further enhance the experiential component of our model. When we do this, we enhance our student's probability of success.

We then created a sustainable relational model, shown in Figure 1, to dynamically tie Research, Academic, and Industry, including government and other institutions (from now on referred as external). These interrelationships are not serial nor are they discrete; they are holistic and concurrent. We call the model relational because developmental and research projects are aligned with industry needs and allow us to create the customer-supplier relationship instead of relying only on transactional type of projects where the university students and faculty execute with no internal follow up either within the industry or within the university.

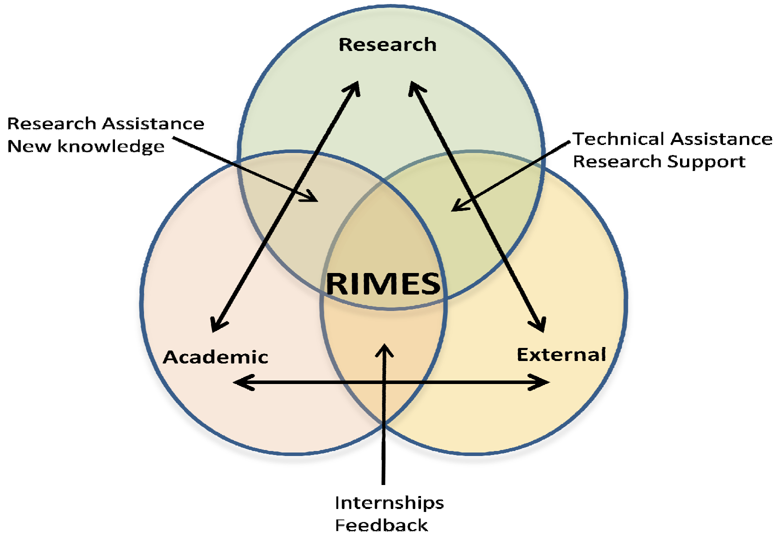

Figure 1. RIMES Sustainable Relational Model

It shows that the Research-External interrelationship is bidirectional and includes developmental and applied research for technical assistance on specific industry problems or opportunities.[1] It also involves Executive Courses directed at private industry. In the other direction the interrelationship includes sponsorship for research, case studies, and further research areas of opportunity. This models the actual tasks of students and faculty hired to work on specific research in the university or on site with the companies or government units.

The Research-Academic interrelationship is also bidirectional and includes the generation of new knowledge and the dissemination of this knowledge in one direction and research assistance and ideas flow in the other direction. This also models our commitment to include significant project work in all courses and to include a project practicum course in every program. A significant proportion of students who desire to do so, are appointed as Research Assistants during different periods in their academic careers. We have significant numbers of students from the fields of Electrical, Industrial, and Mechanical engineering and a few students from Metallurgical, Computer Science, Business, Liberal Arts and even Geology.[2] This multi-disciplinary approach models Systems Engineering concepts for our students and thus supports our second principle above.

Lastly the Academic-External interrelationship is again bidirectional and includes, in one direction, internships, coop agreements, and ultimately the placement of graduate engineers at the external entity. In the other direction, we obtain valuable feedback from these external stakeholders about our coursework, approach, our goals, and programs in general. The primary vehicles are continuous communication with these customers and the guidance of our advisory board to facilitate this interface between Academic and External constituencies. This also

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[1] This also includes attendance at conferences and presentations.

[2] This diversity is due primarily to two factors. One is that the word spreads among student networks and secondly the projects themselves are getting more and more diverse.

models our commitment to expose our students to External learning situations whenever possible.

4. MSSE Program Achievements, Outcomes and Successes

Over a period of three years the MSSE program has been growing steadily at a rate of 40% per year in student numbers and at 200% in industry and government funding. 100% of our students have graduated with a pre-professional experience of at least 500 hours in private industry projects and 98% of them obtained job offers prior to graduating or are currently working professionals (employers include Fort Bliss, White Sands Missile Range, Lockheed Martin Aeronautics, Boeing, Raytheon, and Ysleta School District); in addition, we have enabled multidisciplinary education by engaging students from varied backgrounds including EE, IE, ME, MME, Business, and Social Science.

We have established a very strong Advisory Board to provide input on industry expectations, to guide us in the definition of a vision and mission for the programs, to review curriculum and course content, to advise on creation of projects and areas of research of interest to the industry, and to help us track the program progress and to compare with national and international standards. Advisory Board members include: LMC-Aeronautics, Jacobs Engineering, Raytheon, NASA, WSMR, FAA, Sandia National Labs, Miratek, INCOSE Enchantment Chapter, and MIT.

We have an INCOSE student chapter which is the fastest growing within the enchantment region in INCOSE and have already signed a credentialing agreement with INCOSE to help our students and professionals with ASEP certification.

In research we enabled multi-disciplines by engaging EE, IE, Environmental, CE, Materials engineering, Geological Science in projects led by different industries including LMC-Aeronautics, Jacobs Engineering, GDC C4 Systems, WSMR, AFRL, LMC- Advanced Development Projects, Hamilton Sundstrand, Raytheon and others accounting for over 45 developmental and research projects and more than 30 technical assistance projects.

Assessment of outcomes and objectives follow ABET guidelines. Mastery for outcomes outlined in section 2.3 above are assessed through evaluations at the peer level within in-class and industry projects (on-site and on-campus); we also assess the level of mastery through course examinations and industry partners evaluations of the technical presentations. Another indicator of mastery is the presentation of papers at various conferences. Lastly, a critical validation of mastery is the fact that almost all of our graduates entertain multiple offers before graduation even in an adverse economic environment.

The program has defined five principal educational objectives which encourage our graduates to:

- assume leadership responsibilities in their field,
- innovate new products, services, and systems,
- discover new knowledge and develop new tools,
- earn professional recognition and be valued for their skills, and
- collaborate and generate benefits for their community, profession, and society.

The program is too new to have fully matured educational objectives data, but we have processes in place which have begun to provide useful information as feedback. Our processes include entry and exit interviews for all graduates, personal relationships and conversations; we maintain almost monthly contact with our alumni. For feedback on the appropriateness of the educational objectives, we rely on employer surveys, publications, and advisory board feedback. Preliminary data indicate our graduates are valued for their attitudes as well as hard and soft skills.

5. Conclusions and Future Work

The successes we have had over a short period of time have shown us that to get the unrestricted commitment from industries, for practice based learning, alignment of university research and developmental projects with the corporate strategy are of upmost importance to get buy-in from the highest executive levels within the corporations. Our students have faced tremendous challenges when presenting their work at the highest executive levels but at the same time they feel much energized to self-learn once they return to the class environment after the practice.

Once the support at the highest corporate level is obtained a planning process with multi-year financial and technical commitments is necessary to define PBL and experiential learning projects or research areas that have a transfer of knowledge and have a follow up within the corporation and the university via close communications between the PM and the PI; this early definition allow our students to work on projects when they report to the practice with an understanding of their responsibilities and commitments. A challenge within this process is to get the university and the faculty members embrace and understand the corporate environment and the corporation practices. This challenge has to do with the different cultures and pressures e.g., industry more interested in stakeholder value-added, on increased competitiveness and processes improvement, etc. while the academic culture is more gear toward insightful papers, basic fundamental research, and individual reward systems; our experience shows that the model works better when the involved faculty have been also industry practitioners.

To have the continuity in the process and create the desired relationships the PM within the corporation and the PI must not only advocate for the projects within their organizations but also be a catalyst to disseminate the work and results through awareness efforts thus generating new opportunities for expansion.

Recent research findings on the best practices for industry-university collaboration[8] seem to validate our relational model and points out the need to enhance our model by examining the set of best practices against our model basic premises.

There are some questions in our minds about the sustainability of the model if we keep growing at the rate we have been growing over the last 3 years; can we keep sending our students to a semester long (summer) practice when the numbers are 40 or more per semester? Should we cap our enrollment if our working principles are threatened? How many companies and industries are really willing to commit to a sizeable investment to get engineering students into a practice based curriculum? Should there be any government agencies support in a similar manner as the one in place for medical schools? Is our model a point solution or can it be extended to all the engineering fields?

As part of the planned future work we are looking into ways to address these major concerns to extend the model to other engineering disciplines.

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