Model for Integrating Entrepreneurial Mindset Education and Experiences in Engineering Students

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***Abstract*—This paper examines the issues of transforming educational experience of our undergraduate engineering students in order to develop the entrepreneurial mindset. Entrepreneurial mindset attributes include critical thinking, innovation, the understanding of the value of input and feedback from diverse perspectives and cultures, basic knowledge of business practices, experience working in and leading interdisciplinary and multidisciplinary teams, effective listening and communication skills, the understanding of how to develop and bring products to market. These attributes are not learned in books, but rather through practice in different settings and in "learning by doing". A model for integrating entrepreneurial mindset attributes including problem based learning, active collaborative learning, interdisciplinary teams and the understanding how to bring products to market is presented.**

Keywords—entrepreneurial mind set: engineering curriculum; problem based learning

I. INTRODUCTION

Knowledge based employment generally refers to combinations of disciplines associated with science, engineering, technology and mathematics. Engineering lies at the nexus of the creation of new technologies, translational research that converts new science to practical applications, and product development that leads to viability in the market place. These, with a strong entrepreneurial flavor are the primary ingredients of any plan to move the nation toward a healthy knowledge-based economy. Because engineers, particularly those with business skills, can create high technology, high pay enterprises even in a weak economy, engineers with business skills should be viewed as catalysts for job growth. Educational pipeline that produce engineers, particularly engineers with entrepreneurial skills, should be viewed as key to nation's economic future. Over the past few years, the focus on economy has motivated many Universities to advance its efforts to develop an entrepreneurial engineering program.

Ensuring that all students achieve an entrepreneurial mindset begins with curricular revisions that include modifying courses, supplementing coursework with activities outside of the classroom; the author proposes a model for integrating entrepreneurial mindset education and experiences in engineering and technology. Students Entrepreneurial mindset attributes include critical thinking, creativity, innovation, the understanding of the value of input and feedback from diverse perspectives and cultures, basic knowledge of business practices, experience working in and leading interdisciplinary and multidisciplinary teams, effective listening and communication skills, the understanding of how to develop and bring products to market and leading groups, projects or other activities that provide leadership experience. These attributes are not learned in books, but rather through practice in different settings and in "learning by doing". The vision of graduating engineering students with an entrepreneurial mindset is achieved by:

- transforming educational experience of undergraduate engineering students in order to develop the entrepreneurial mindset
- providing an infrastructure to encourage and support entrepreneurial experience of our engineering and technology students
- facilitating a set of in-depth learning interactions that provide the depth of knowledge in engineering entrepreneurship
- developing a set of course modules by modifying major courses to include

entrepreneurship concepts throughout the entire academic career, altering courses to include problem based learning and open ended projects, and developing multi-discipline capstone design experiences.

This paper explores a model for integrating entrepreneurial mindset attributes that include critical thinking, creativity, innovation, problem based learning, active collaborative learning, experience working in interdisciplinary teams and the understanding of how to develop and bring products to market.

II. INNOVATIONS AND INSTITUTIONAL STRATEGIES

In the last decade, there have been several attempts by educational institutions to develop innovative engineering curriculum. Recent educational reforms have highlighted the benefits of pedagogies which catalyze students to be active participants in the learning process and which present knowledge as socially constructed. As *Duderstadt* 2008[1] notes, "In a global knowledge driven economy, technological innovation, transformation of knowledge into products, processes and services is critical to competitiveness, long term growth and the generation of wealth. Studies show that scientific understanding develops best when students become active partners in learning, and when they can refine their interpretations through collaboration with peers and mentors." Toward this end, the language of science instruction is laden with such terms and concepts as "learning through doing", "hands-on experiences", and "discovery-oriented learning." There had been several studies such as *Rising Above the Gathering Storm* by the Committee on Science, Engineering and Public Policy, 2007 [2], *Invention and Impact: Building excellence in Undergraduate STEM education*, a report from a report from National Academy of Engineering (NAE) [3], *Engineering Curricula: Understanding the Design Space and Exploiting the Opportunities* from NAE, 2010[4].

These studies clearly point out the challenges in maintaining leadership in technological innovation and recommend bold and transformative approaches. The studies recommend systemic approach to the reform of engineering education by redefining the roles of engineers with the technological innovation to create the products, processes, and services needed by the society[5][6]. Since engineers with strong entrepreneurial skills are better equipped to create high-technology, high-return market opportunities the educational program that cultivates engineers with entrepreneurial skills is an important ingredient to improving the nation's future [7][8].

III. GOALS OF ENTREPRENEURIAL ENGINEERING PROGRAM

Engineering Curriculum

The integration of applied research and contextualized design throughout the engineering curriculum starts from a design-based, freshman-level course and progressing through intermediate courses at the sophomore and junior level, culminating in the capstone design experience at the senior level. The engineering and interdisciplinary courses in the sophomore and Junior years include built-in collaborative projects. In the senior year students have the opportunity to work on well-rounded projects sponsored by outside agencies. The introduction of design-oriented courses in each year of the curriculum (design sequence) has given the students an opportunity to make connections between various courses and obtain a better perspective of engineering practiced in the industry. These courses and design projects provide the skills in problem solving, communication, ethics and team building skills but stop short of taking these designs and evaluate their commercial potential.

Curriculum Related

The major intention is to develop entrepreneurial mindset by transforming the educational experience of the undergraduate engineering students. This is accomplished by developing set of course modules and by modifying major courses to include entrepreneurial concepts throughout their academic career, altering courses to include problem based learning and open ended projects, and developing multi-discipline capstone design experiences with entrepreneurial components.

To achieve this transformation of the educational experience of students, it is imperative that the faculty and leadership have to understand the entrepreneurial mindset and they themselves have to become entrepreneurial individuals in educating our students. Creating an entrepreneurial mindset in all engineering students requires a new pedagogy and approach to student learning – faculty must take risks in the classroom and practice the attributes that will develop an entrepreneurial mindset.[9][10][11]

Infrastructure Related

To provide an infrastructure to encourage and support entrepreneurial experience of engineering students. The infrastructure will have to facilitate a set of in-depth learning interactions that provide the depth of knowledge in engineering entrepreneurship. Entrepreneurial Projects, Entrepreneurial Co-ops and Internships, the Entrepreneur in Residence, and the

Regional Entrepreneurial Student Competition are some of the examples of sustainable activities.

1) How Do We Instill Entrepreneurial Attributes?

The characteristic of an entrepreneurial engineer are integrity, tenacity, ethics, creativity, deep knowledge of engineering fundamentals, ability to engineer products for commercialization, a penchant for lifelong learning, an ability to see how their ideas fit into the larger context of the society, and proficiency in communicating his or her ideas.

The entrepreneurially minded engineer has the desire to focus on business growth and support other employees who are both the generators of new ideas and the supporters of new ideas. The approach is to instill these characteristics in undergraduate education, so that the graduates are better prepared to enter an entrepreneurial workforce to the technical advantage of the business in which they work.[12]

Without affecting their fundamental technical skills the undergraduates are taught the major entrepreneurial characteristics: engineering knowledge required to commercialize an innovative concept to make it market-worthy including customer awareness; business acumen; and personal character to maintain our societal values.

Figure 1 shows a process flow chart of how the entrepreneurial mind set will be instilled systematically. The entrepreneurial engineering attributes are included in class discussions, in case studies, in general discussions, in guest lectures, and in example problems. Co-curricular experiences which take place outside the class room are opportunities such as workshops, seminars, lecture series and cooperative work experiences. Extracurricular experiences take the form of competitions or internship work experiences, professional society meetings field trips or boot camps. Underlying the pedagogical initiatives is the sustaining support from the College and the University.

Figure 2 shows the sequence of four courses taken by students in each year from the freshman to senior year. *Engineering and Design* course in the freshman year has an emphasis on guided design and problem solving methodologies. Students undertake a practice oriented group design project.

In the sophomore *Engineering by Design course*, students undertake in-depth study of the design process to include evaluation of alternate solutions, economic analysis, ethical constraints, and group dynamics.

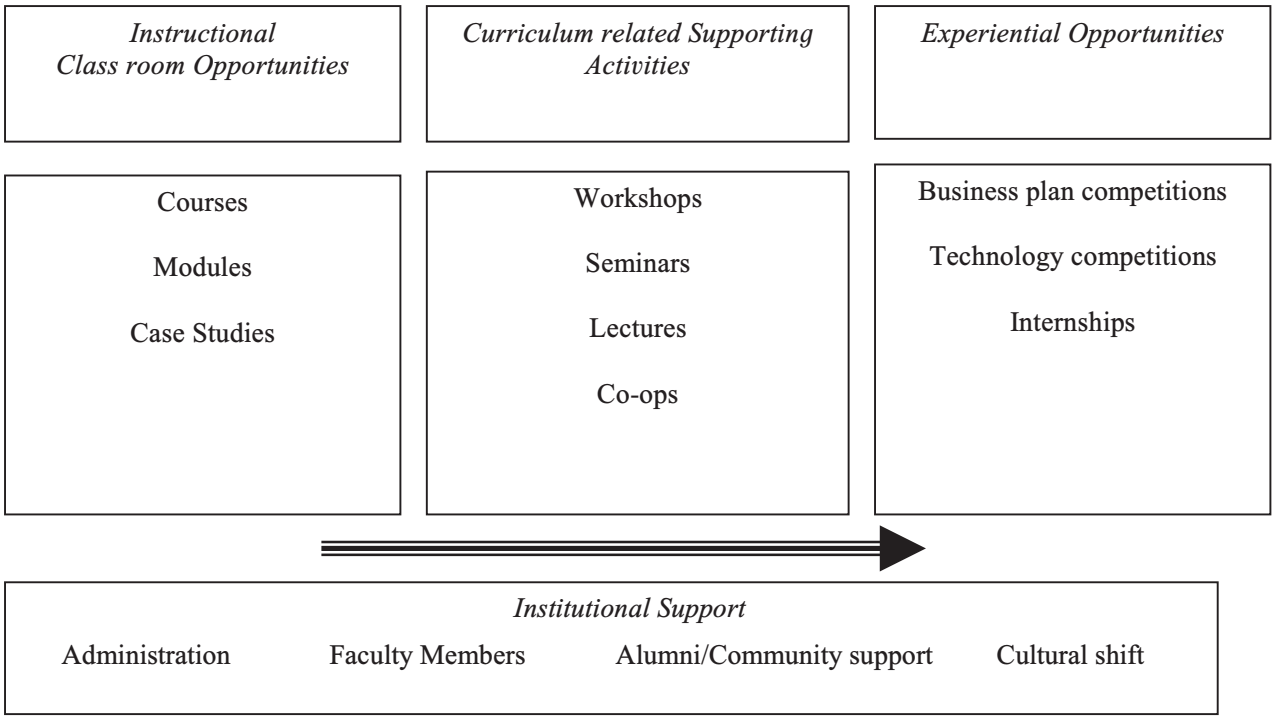

Figure 1: *Flow chart for instilling entrepreneurial mindset (Based on Timothy Kriewall (7))*

In the junior year *Engineering Practice course*, the students are introduced to factors such as impact on society, political concerns, and cultural concerns that significantly affect their designs, but are not part of traditional engineering design environmental impact and financial viability.

Senior Year of curriculum culminates in a *capstone project*, normally sponsored by industries supervised by engineering faculty with consultation from a business/industrial counterpart.

Considerable effort is expended in the engineering curriculum in teaching the engineering design process where students apply mathematical and scientific principles to create systems and products. Students can develop an entrepreneurial mindset since they are focused on real business objectives besides engineering design objectives. They will come to understand that technical success and commercial success have different criteria and to deliver real value to their enterprise, they have to focus on the often more demanding criteria of commercial success. The outcome of this major initiative is for engineering students to practice the attributes of the entrepreneurial mindset as they learn specific subject matter in their courses.[13]

- Modifying core courses to include problem- based learning, team-based learning and open-ended projects
- Adding co-curricular activities that develop entrepreneurial mindset attributes in collaboration with University leadership
- Developing multidiscipline capstone design experiences with entrepreneurial components
- Evaluation of the required courses taken by all the students
- Assessment of student learning will be conducted by: 1) pre- and post-tests for each course will be developed and given to the students to show the extent students in the modified courses learn and apply the attributes of the entrepreneurial mindset; and 2) the comparison of students taking the modified course with students taking the same course in the traditional format will serve as a baseline for assessing student learning improvement

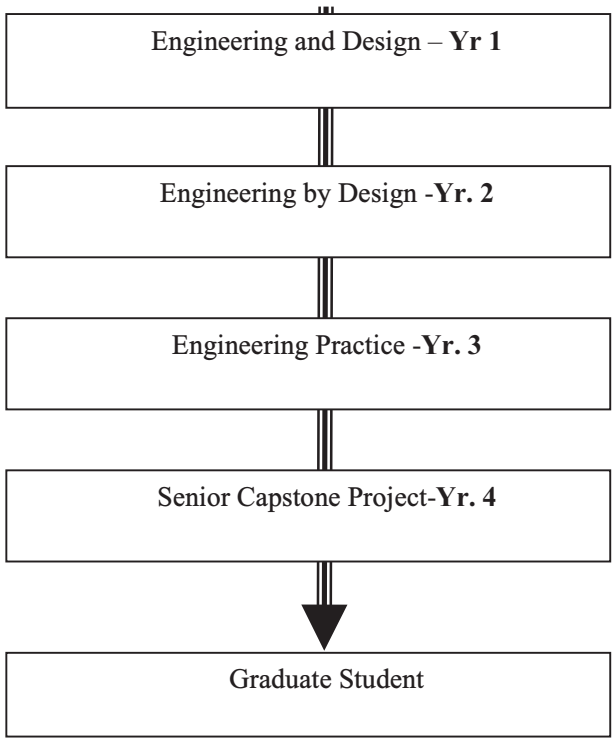

Figure 2: *Sequence of Courses to be modified*

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2) Multidisciplinary Entrepreneurial Student Projects

The engineering students learn the attributes of the entrepreneurial mindset as they participate as team members and leaders in interdisciplinary entrepreneurial student enterprise projects. The strategy for student engineering enterprises involves groups of students forming companies on campus to make a product or complete an engineering project. [14][15]

3) Culture change of faculty and leadership

Participation in interdisciplinary team projects provide opportunities for engineering students to solve real-world problems, perform testing, analyses, build prototypes, manufacture parts, stay within budget, manage multiple projects, understand business acumen, work with people representing different areas of expertise, improve communication skills, tolerate ambiguity, take risks, and demonstrate many other attributes of the entrepreneurial mindset[14]. The additional benefits that accrue by project participation are:

- Access to industry sponsored projects
- Incentives for interdisciplinary entrepreneurial teams
- Access to coaching opportunities for engineering students on issues such as obtaining venture capital, market branding, and intellectual property

The metrics for these projects include:

- Number of projects developed and disciplines involved
- Number of students and diversity of students involved
- Student evaluation of entrepreneurial experiences and project presentation
- Industry/business evaluations of projects

The culture change of faculty and leadership is achieved by the delivery of two types of workshops throughout the duration of this program: (a) Faculty Entrepreneurial Mindset Workshops and (b) University Leadership Entrepreneurial Mindset Workshops. These workshops are conducted by leading experts and focus on problem based learning and active collaborative learning.

The outcomes of this initiative are:

- To develop the entrepreneurial mindset and culture within the faculty that supports engineering students.
- To develop support for embedding entrepreneurship values into each class of the engineering curriculum.
- To develop a faculty community of practice that supports the transformation of engineering undergraduate education

Infrastructure related

There are three components to support the students in their entrepreneurial activities and projects: They include the Entrepreneur in Residence, Entrepreneurial Co-ops and Internships, and the Regional Entrepreneurial Student Competition.

The "entrepreneur in residence" does the following activities:

- Advice student/faculty teams working on engineering enterprise projects to help these teams to identify and solve the problems from an entrepreneur's perspective
- Advise faculty to assure that modifications to existing engineering courses contribute to the development of the entrepreneurial mindset
- Identify and recruit external speakers for the Entrepreneurial Seminar Series
- Coordinate and contribute to the development and implementation of the yearly workshops to educate faculty and administration
- Contribute to the dissemination of this project at professional and national conferences
- Help in the assessment and in the collection of data that will measure the success of this program
- Advise start-ups and aspiring entrepreneurs

Entrepreneurial Co-ops and Internships

The outcomes sought are:

- To shift the mindset of engineering students from one that traditionally emphasizes employment and careers at mid-size to large companies to one that seeks employment and careers at higher risk technology startups and small businesses

- To demonstrate the benefits of working in a technology startup or small business

Entrepreneur Innovation Student Competition

The outcome of this initiative is to encourage and develop in engineering students the attitudes of innovation, identifying unmet needs, developing new products, and delivering value to customers. This one-day competition will include the regional schools and Universities. Multidisciplinary student teams participate in an innovation quest competition that builds innovative skills using a structured approach to solve specific real-world problems. Industry sponsors can be encouraged to provide real-world engineering problems for the student teams. The student participants will be given a scenario for which they will have to define the need, develop a product, explain how the product meets the need, and explain how the product will be marketed to the customer.

IV. HOW DO WE KNOW THAT WE ARE MEETING THE GOALS

To assess the success of the model, the program has to develop a comprehensive assessment and program evaluation plan that includes collection of quantitative and qualitative data. The evaluation plan consists of two components: **1)** Overall evaluation of the program and individual program components by various constituents (students, faculty, alumni, and industry) and **2)** Assessment of student learning associated with program learning outcomes (i.e. development of the entrepreneurial mindset).

Evaluation Rubrics

The following are some of the examples that show how some of the activities will be evaluated:

Assessment and Evaluation: On a scale of 1 – 5 with 5 best, how well does the institution assess itself on effectiveness of instilling entrepreneurial skills/attributes/ principles into the knowledge of its graduates?

Creativity, Innovation and IP in Curriculum: On a scale of 1 – 5 with 5 best, how well does the faculty of this program address innovation and creativity as part of engineering fundamentals through the curriculum?

Business Acumen in Courses: On a scale of 1 – 5 with 5 best, does institution offer courses which address business acumen development through the curriculum, including basic business analysis teaching economics, financial analysis, P&L, balance sheets, cash flow, capital depreciation; organizational management including cross-functional team effectiveness, conflict resolution, interpersonal communication skills, standard operating procedures and adherence to corporate business practices?

Students' Understanding of Free Enterprise, Integrity and Ethics: On a scale of 1 – 5 with 5 best, how well do the students understand issues of free enterprise, personal character, integrity, ethics and political involvement?

Ethical Business Behavior in Students: On a scale of 1 – 5 with 5 best, does the institution have courses for the e-ship engineering students to learn about ethical business behavior?

Business Interactions: On a scale of 1 – 5 with 5 best, how well does this institution reach out to the business community to bring entrepreneurship and intrapreneurship experiences into the pedagogy of the engineering curricula?

Internships/co-ops: On a scale of 1 – 5 with 5 best, how well does this institution promote experiential learning experiences for its engineering students?

Service Learning: On a scale of 1 – 5 with 5 best, how involved are students and faculty with service learning and service projects outside the college? (Service learning is volunteer work outside the institution that leads students to the realization that helping others is critical to leadership and business success.)

V. CONCLUSIONS

Our world has changed more in the past 100 years than in all those preceding, and scientific and engineering knowledge presently doubles every ten years. The important role that engineers play in this ever-changing globally competitive world is also changing. The engineering student must evolve from a "problem solver" to an "opportunity and business creator." The engineer must go from a supporting role within the development process to the leader of that process. The engineer must no longer be educated to support and work in a corporate infrastructure but instead must be educated to develop new ones. The entrepreneurship mind set must be developed in this generation of graduates for our and their own economic survival.

This paper looks at a model of providing an educational experience to all engineering undergraduate students that will build incrementally on their entrepreneurial skills and knowledge. The curricular revisions include modifying courses, supplementing coursework with activities outside of the classroom, facilitating cross-disciplinary thinking and providing students with direct access to entrepreneurial mentors who have founded their own startup companies.

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REFERENCES

[1] James Duderstadt, " Engineering for a Changing World-a Roadmap for the future of Engineering Practice, Research, and Education " The Millenium Project, University of Michigan, Ann Arbor, MI 2008.

[2] "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future Committee on Prospering in the Global Economy of the 21st Century" The National Academies Press, Washington DC 2008.

[3] "Building Excellence in Undergraduate Science, Technology, Engineering, and Mathematics (STEM) Education", Report from an AAAS; Advancing Science and Serving Society, 2008, http://www.aaas.org/publications/books_reports/CCLI

[4] "Engineering Curricula: Understanding the Design Space and Exploiting the Opportunities" NAE Report, The National Academies Press, Washington DC. 2010

[5] Timothy Kriewall, "Instilling Entrepreneurial Engineering Mindset in College Undergraduates" Keynote paper, NCIIA March 25-27, 2010, San Francisco.

[6] Hadim, H.A. and Esche, S.K., "Enhancing the Engineering Curriculum through Project-Based Learning," Proceedings of the 32nd ASEE/IEEE Frontier in Education Conference, November 6-9, 2002, Boston, MA, Section F3F, pp. 1-6.

[7] S. Fredholm, J. Krejcarek, S. Krumholz, S and D. Linquist, "Designing an Engineering Entrepreneurship Curriculum for Olin College" Proc. ASEE annual conference and Exhibition, 2002.

[8] Witt, H.J., Alabart, J.R., Giralt, F., Herrero, J., Medir, M., and Fabregat, A., "Development of Coaching Competencies in Students through a Project-Based Cooperative Learning Approach," Proceedings of the 32nd ASEE/IEEE Frontier in Education Conference, November 6-9, 2002, Boston, MA, Section F2A, pp. 1-6.

[9] Ju, W., Oehlberg, L., and Leifer, L., "Project-Based Learning for Experimental Design Research," Proceedings of International Engineering and Product Design Education Conference, September 2-3, 2004, Delft, the Netherlands.

[10] Slivovsky, L. A., and Liddicoat, A. A., "Transforming the microprocessor class: Expanding learning objectives with soft core processors," 37th ASEE Annual Conference, Hawaii, June 2007.

[11]Friesen, M. and Taylor, K. L., "Perceptions and Experiences of Industry Co-Operators in Project-Based Design Courses," International Journal of Engineering Education, Vol. 23, No. 1, pp, 114-119, 2007.

[12]Gorman, M. E., Johnson, V. S., Ben-Arieh, D. Bhattacharyya, S., Eberhart, S., Glower, J., et al., "Transforming the Engineering Curriculum: Lessons Learned from a summer at Boeing," Journal of Engineering Education, Vol. 90, No. 1, pp, 143-149, 2001.

[13]Nicolai, L. M., "Viewpoint: an Industry View of Engineering Design Education," International Journal of Engineering Education, Vol. 14, No. 1, pp. 7-13, 1998.

[14]Devdas Shetty, "Virtual Product Design Using Innovative Mechatronics Techniques for Global Supply Chain. IMECE ASME Engineering Congress & Exposition, IMECE 2011-64228, Denver, CO, November 2011.

[15]Devdas Shetty, "Product Design for Engineers" Published by Cengage Publishing Co. Toronto, February 15, 2015