The Implementation of Senior Design Capstone Projects Combining Engineering and Business Students

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In order to address complex and multi-disciplinary world problems, it is necessary to create a diverse engineering work force composed of competent and creative individuals prepared to meet current and future global challenges. The entrepreneurial skillset has become increasingly important in this area; the vocational skills that a student learns can be augmented by an understanding of how business operates as well as an appreciation that enterprise skills can be applied within an organization. Traditional university programs lack the teaching methods to turn today's students into innovative and creative leaders who can integrate both the engineering and business skills necessary to succeed in this technology driven global economy. The developed curriculum integrates engineering skills with entrepreneurial creativity by placing engineering and business students on the same projects in the same physical space to facilitate cross-pollination of knowledge in a collaborative learning environment to create technology savvy entrepreneurs. This paper outlines the curriculum framework, a discussion of the resources required, overviews of typical industry projects, a discussion of evaluation criteria, and a discussion of the benefits.

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Introduction

"Our world is changing at an accelerated pace and the boundaries between disciplines are blurring. Under these dynamic conditions, we face global challenges at a scale never before seen. The new age of engineering is at the great intersection of left brain and right brain engineering; three core concepts will shape the future: whole-brain engineering, collaboration, and balance."

---Dr. Julio Ottino, Dean of the Robert R. McCormick School of Engineering and Applied Sciences at Northwestern University

The goal of the research was to transform the way engineering students learn through the development and implementation of an interdisciplinary capstone course that involves heavy interaction with industry to develop new products and business plans. The design projects involved the creation of multidisciplinary design teams comprised of engineering students, business students, engineering faculty, business faculty, entrepreneurs, and professional engineers. The primary objectives included increasing student interest and achievement, enhancing student experience to simulate real world business interactions, stimulating student interest in entrepreneurship and innovation, and increasing faculty member's knowledge.

A cross-functional capstone course is well established in management and business pedagogy, but not as heavily utilized in engineering[1]. The Accreditation Board for Engineering and Technology (ABET) emphasizes the need for engineering courses that build teamwork, communication, and project based skills. An interdisciplinary capstone course aids in building and enhancing these skill sets. This paper provides a framework and the related support structures required for implementing interdisciplinary engineering and business capstone projects.

Literature Review

This research is novel and transformative in several key ways; first, few engineering programs in the US teach this much needed entrepreneurial mindset[2-3]. Collaborative learning has been shown to increase individual learning through co-construction and personal reflection[4-5]. At a time when accreditation requirements and professional licensure examinations have become the metric for student achievement at engineering institutions, instructors often focus on narrow objectives leaving little time to address legitimate student inquiry to build these skillsets at the early stages on one's college studies[6]. If students are to be prepared to meet current and future challenges, engineering students must work effectively in teams to assess needs and to co-create solutions while considering both social and economic implications[7]. Thus, from a value proposition perspective, providing an educational environment for engineering students that nurture creativity, collaboration, and entrepreneurial design is likely to result in positive life-altering consequences. This research can provide the

foundation to better understand and exploit how engineering students learn in dynamic, multidisciplinary, and opened-ended environments.

Curriculum Framework

Figure 1 on provides a conceptual overview of framework for the implementation of the combined capstone projects.

this method will place them in a stronger position to be successful as they move into the workforce upon graduation. In this paper, the authors draw upon their experience in the College of Engineering and the College of Business and Innovation integrating the capstone course and senior design clinic into the curriculum.

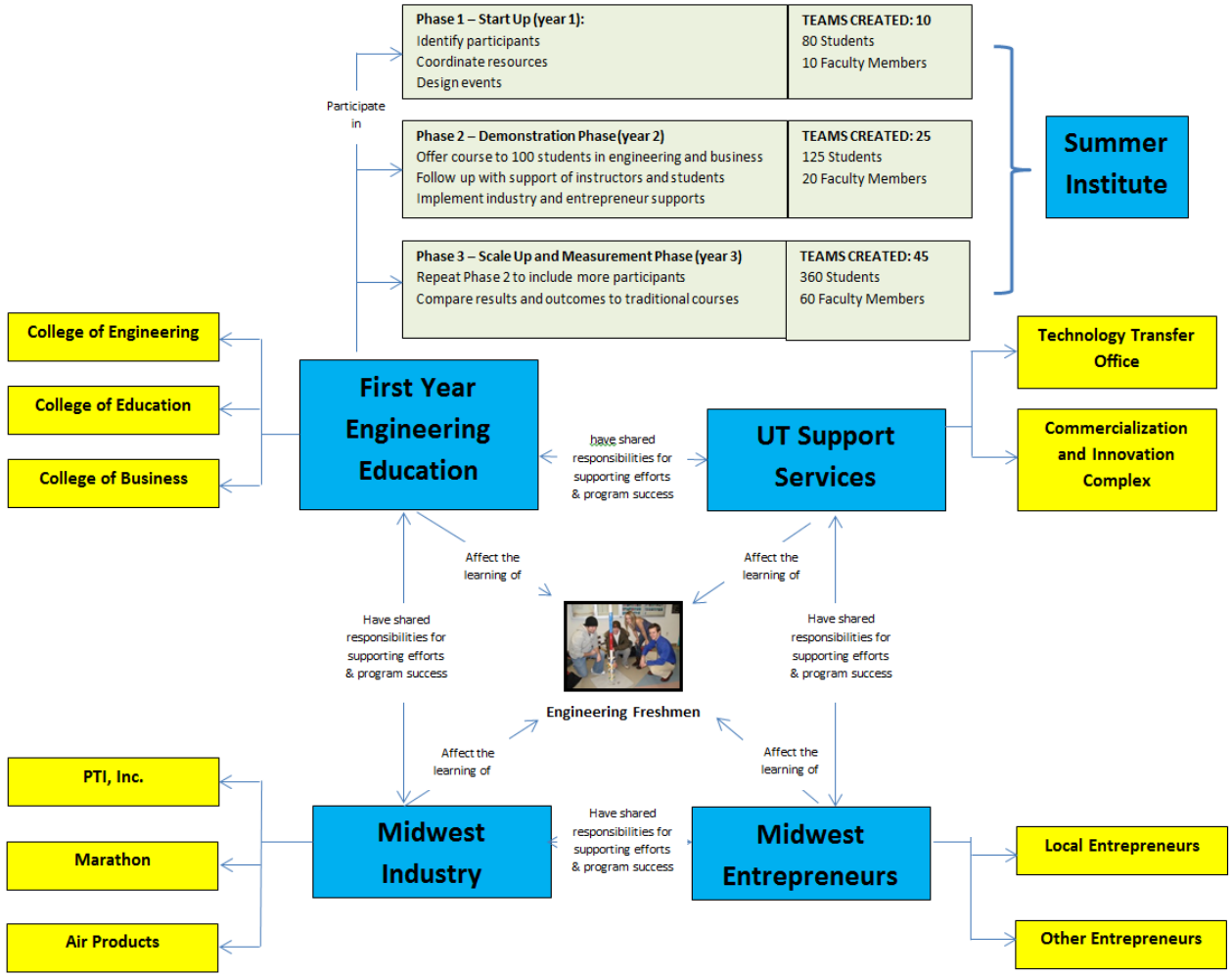

Figure 1: Curriculum Framework

This framework enhanced industry collaboration as it provides a systematic approach to establish a common meetings space, problem resolution guidelines, addresses technology transfer, and assesses client satisfaction levels. These efforts have progressed to combine engineering and business students on the same projects to foster cross-pollination of skill sets and simulate real world team environments. Advantages of the combined capstone course are that it facilitates a deep as opposed to surface learning and enhances communication skills. As engineers are called upon to work in cross functional teams, the skills learned using

Resource Requirements

Extensive resource requirements and planning were needed for the combined senior capstone projects. Faculty members in both the College of Engineering and the College of Business and Innovation were identified and assigned to the combined course. Work space was required for the student teams to meet and build their prototypes. Industry and entrepreneurial advisors were identified and assigned to the project team to assist the students in the design of their prototypes and analysis of their business plans.

Potential projects were identified working with industry advisors and faculty. Finally, the University's Technology Transfer Office was contacted to develop protocols, processes, and agreements. Typically, one faculty member serves as Course Director and is in charge of all administrative aspects of the course, including identifying the projects to be conducted by the students. Each group is supervised by a Faculty Advisor (Project Technical Advisor) and a Client Advisor. The Project Technical Advisor and the Client Advisor meet with their groups on a weekly basis.

Administration of the Course

The University of Toledo, through its Department of Mechanical Engineering (College of Engineering) and the Department of Management (College of Business) accelerated the formation of new ventures by developing an innovative collaboration involving senior mechanical engineering design students and senior students majoring in entrepreneurship from the College of Business. This collaboration involved merging the two senior capstone courses for each major to create a new combined course. The course focused on synthesizing engineering and business skills with entrepreneurial creativity to transform our students into creative, innovative, and global leaders who understand how to capitalize on technological advances and transform them into business opportunities.

The Senior Design Clinic is a joint collaboration among the Mechanical Engineering Department Senior Design students, faculty and industries. As participants in the clinic, students work in teams using knowledge gained in earlier courses to solve real world design, manufacturing and operational problems relevant to industries. Oral and written communications with participating companies as well as teamwork are stressed. Other topics include design for manufacturing, patents, product liability, safety, ethics, technical report writing, and presentation skills. Industries play a major role in the success of this program by providing an engineering project challenge and technical as well as financial support. As members of the clinic, the industries seek and obtain a solution to a specific engineering project or problem relevant to their organization within a short time. Secure laboratory space is provided for the students and clients that is equipped with computers, fax, phone, hand tools, and dedicated workspace.

The primary purpose of the senior design clinic was to form a partnership between academic and industry and enhance their senior design capstone course experience. Students would take the skills they garnered through their three or more mandatory cooperative education experiences and use them to perform as a consulting team during the senior design clinic experience. The clinic was the administrative and financial side of the academic experience. Course work was delivered by a faculty member whereas the consulting activities were administered by the clinic director. Additionally, students were given parameters in regards to leadership roles, budgetary preparation, peer evaluation, travel expenses and reporting and accountability to their team. All of these expectations prepared the students to enter the work force full time upon graduation.

Phase One Implementation and Project Examples

During the first semester of implementation in fall 2013, Phase 1 displayed previously in Figure 1 was implemented. Ten teams of eight students were created (composed of five engineering students and three business students). Each team was assigned one engineering faculty member and one business faculty member as faculty advisors, one industry advisor, and one entrepreneurial advisor. Sample projects from the first semester of implementation included:

- The development of a device and procedure to remove blood clots;
- A development of a power assisted wheelchair;
- The development a universal device to open jars and bottles for individuals with disabilities;
- The development of a process to sort post-consumer plastics for recycling using electromagnetic waves and ferro fluids; and
- The development of an autonomous flying drone to detect and fight forest fires.

Each project involved the development of a prototype and the creation of a business plan over the 16 week semester.

Technology Transfer and Intellectual Property

Considering that the end result of the project is a technological project and business plan, students had a tremendous opportunity to learn about technology transfer and intellectual property. The Design Clinic integrated this into the course by dedicating one lecture period to the related issues. A Patent Lawyer from the University's Technology Transfer Department provided a presentation and question/answer session that covered patents, trademarks, commercialization, and entrepreneurship. The Patent Lawyer also discussed the University's role in technology transfer, the evaluation of potential ideas using a standardized process, financial support inside and outside of the University, and legal

aspects associated with working with an outside client on a new design.

Assessment of Learning Outcomes

The achievement of course outcomes was assessed through instructor evaluations of final products, student questionnaires, and a faculty and advisor focus group assessment. The instructor evaluations assessed the quality of the final prototypes and business plans based on the following scale: 1 = poor, 2 = below adequate, 3 = adequate level, 4 = high level, and 5 = excellent. The final prototype evaluations for the ten projects received a mean score of 4.2 with a standard deviation of 0.9 and the business plans received a mean score of 3.9 with a standard deviation of 1.3. The student questionnaires measured the students' perceptions on the quality of the course based on the following scale: 1 = excellent, 2 = high level, 3 = adequate level, 4 = below adequate, 5 = none or not covered. The overall quality of the course received a mean score of 1.7 with a standard deviation of 0.6. Overall, the faculty members and chairs were satisfied with the results and felt that learning outcomes were met.

Conclusions and Future Directions

The combined course integrated engineering skills with entrepreneurial creativity to facilitate cross-pollination of knowledge in a collaborative learning environment. The goal was to significantly enhance and connect the existing engineering capstone design course and the business capstone course to create 'new age engineers and entrepreneurs' by combining engineering and business students. The combined course tested the feasibility of entrepreneurial design courses to better understand how it might affect student achievement and learning outcomes. Significant potential exists for positive educational, social, and environmental impacts. From an educational standpoint, the primary objectives included increased student interest and achievement, enhanced student experience to simulate real world business interactions, stimulated student interest in entrepreneurship and innovation, and increased instructor's knowledge. The ultimate goal of the combined course was to address and improve engineering design and entrepreneurship courses in a boundary-spanning manner to shift the paradigm regarding how we educate engineers and prepare them to enter the workforce.

Future directions for the course relate to implementing Phases 2 and 3 displayed earlier in Figure 1. Ten pilot projects were conducted in the fall 2013 and 25 projected are planned to be implemented in fall 2014. Through Phases 1 and 2, the team will examine several related research questions throughout the project, which will contribute to the relatively scant literature base on integrated entrepreneurial courses. This project will seek to answer three fundamental questions:

1. Is the combined engineering/business program accomplishing its goals?
2. Is the combined engineering/business program a good way to encourage engineering departments to update their programs to incorporate new teaching methods?
3. Is the combined engineering/business program successful at providing a better engineering education for students?

The successful implementation of Phase 1 provided insight into the benefits of integrated senior capstone courses. By implementing and analyzing Phases 2 and 3, the faculty team will be able to push the boundaries of integrated capstone courses, answer the research questions, and generate new information to enhance student learning outcomes.

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