An Engineering / Entrepreneurship Capstone Collaboration: Providing Real-World Experiential Learning

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Piloted in the fall of 2016, a collaboration was launched between the VCU Schools of Engineering and Business. The alliance seeks to bring together traditional Engineering capstone senior design programs and Business School Entrepreneurship capstone courses, creating a robust collaboration between the two, heretofore, very distinct curricula. The intent is to provide students from both disciplines with an experience that mirrors product and business development processes found in most engineering–centric industrial companies. At VCU, the program was the brainchild of the Entrepreneurship program in Business and the capstone design apparatus in Engineering. The first cohort went through the program in 2016-17. Engineering projects were chosen based on the following criteria: (1) Not industrially sponsored: (2) Directed at VCU Health, non-profit and faculty / student sponsors; and (3) Exhibit a clear pathway to a potentially tangible, saleable product. In 2016, 11 Engineering projects meeting these criteria were chosen. Senior, undergraduate Entrepreneurship track business students then bid on the selection of engineering projects. Outcomes were impressive for the first year of the trial – of the 11 projects in the program, two spun out as private, entrepreneurial ventures. In most cases, students and faculty rated the collaboration highly. Areas of improvement were identified and adjusted for the 2017-18 cohort. These included the need to enforce initial interactions between the two disparate teams, and to train faculty advisors and students in the language of the partner department.

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Introduction

The capstone senior design courses in the School of Engineering at Virginia Commonwealth University are configured to allow students to demonstrate skills learned in their undergraduate education. The students work in teams to address open-ended, real-world engineering problems[1-2]. As guided by ABET accreditation criteria[3], projects should match the expectations[4] of employers who recruit BS engineering graduates and provide skills related to an experiential graduate education.

The AACSB (Association to Advance Collegiate Schools of Business) does not have specific guidelines for business school capstone courses, but generally notes various assurance of learning outcomes such as communication, problem-solving, ethical reasoning, language, and technology[5]. Similar to the Engineering School, the capstone courses in the VCU School of Business Entrepreneurship Program intend to develop knowledge and skills of entrepreneurship students, and assess their ability to demonstrate the synthesis of these skills in a team-based approach. This includes generating and evaluating business concepts[5] relevant to new venture formation, with an emphasis on producing and analyzing innovative ideas. The real-world aspects[6] of VCU Engineering capstone projects are addressed by engaging with industrial companies, non-profit entities, and the five health science schools on the VCUHealth (medical) campus, in order to determine and focus on their unmet needs. In the past 5 years, the percentage of projects originating from outside of the Engineering School has increased from 15% to approximately 70%[7]. Student teams engage in engineering design and development through various stages of problem definition, specification performance requirements, conceptualization and ideation, analysis of options, working within defined constraints, identification and assessment of risks, mitigation steps, prototype development and testing, and reporting. At the conclusion of the second semester (in April), teams present their work to sponsors, mentors, faculty, other students, and the public at the capstone design EXPO. Learning experiences also include teamwork, conflict resolution, development of communication skills, and increased awareness of sustainability and global societal factors[8]. A key experiential feature missing in these engineering projects is a rigorous exploration of the entrepreneurial feasibility-- or business potential-- of these projects.

An important element of the capstone design curriculum has been an emphasis on, and creation of, multidisciplinary teams.[9] Engineering literature indicates multi-disciplinary student teams produce better solutions than mono-disciplinary teams[1]. Capstone design surveys confirm this trend to multidisciplinary teams[10-12]. However, a review of the literature searching for collaborations between engineering and business schools (more specifically, entrepreneurship programs) shows a remarkable lack of activity. There is a recent report of a computer science-business collaboration occupying about 4 weeks of one semester[13]. James Madison University reports a business-engineering collaboration revolving around project planning, with the business involvement limited to one semester of a two-year engineering project[14]. Penn State Erie discusses a team-taught multidisciplinary course pairing business and engineering students on teams tasked with developing a product concept, engineering design, and business plan[15]. Other examples of entrepreneurship in engineering capstone are driven from within the engineering school itself [16].

The concentration in Entrepreneurship in the VCU School of Business emphasizes various goals and outcomes, including ability of students to recognize and thoroughly analyze opportunities, build skills in critical thinking and problem solving, create innovative solutions, and pitch concepts to leaders in the business community. Similar to the engineering capstone, entrepreneurship students form teams in order to benefit from students' multiple perspectives, with the expected outcome that teams will generate ideas for business concepts that are not only innovative, but also exhibit potential feasibility and market viability. As with the engineering capstone, the students gain from experiential learning in areas of teamwork, managing conflicts, and building communication skills, as well as developing research skills (in areas such as industry and competition, market, financials, and business plans).

The entrepreneurship capstone is a 2-semester course, taken by all students in the entrepreneurship concentration. Pursuant to the collaboration with engineering, the entrepreneurship capstone culminated in a business plan competition (sponsored by the Association for Corporate Growth, Richmond, VA) at the end of spring semester, with winning teams receiving monetary awards.

A persistent issue prior to the collaboration was the deficiency of innovative concepts generated by the entrepreneurship students. Accompanying this were students who thought of differentiated business ideas, but then lacked sufficient background to understand the design / engineering / specification requirements to create the concept. This is also challenging regarding VCU's "Make it Real" campaign, in that while entrepreneurship student teams conduct research to analyze the feasibility and business potential of their concepts, the concepts have either little market potential (due to lack of differentiation, lack of market demand) or are not realistic (due to lack of students' design capabilities for innovative concepts).

Objectives

In 2013, VCU Engineering established several priorities aimed at augmenting the students' capstone experience:

- Enhance the capstone's value for students by preparing them for a demanding engineering career.
- Design a program mutually benefiting Engineering and area industry and academic partners.
- Assure minimum common standards for capstone projects across engineering departments.
- Meet or exceed ABET accreditation requirements.

VCU Business has offered an Entrepreneurship concentration since 2000. The capstone course's objectives have evolved to include:

- Develop knowledge and capabilities regarding opportunity recognition, concept generation, and the entrepreneurial mindset and process.
- Integrate skills from previous courses to provide a strategic view of new and emerging ventures.
- Train students to generate research resulting in a comprehensive business plan.
- Prepare students to pursue entrepreneurship in its various forms.

Objectives for the collaboration between Engineering and Business Entrepreneurship capstones are:

- Develop a synergistic, entrepreneurship-focused program between Engineering and Business schools.
- Provide entrepreneurship students with realistic new product and/or business ideas founded in sound technology.
- Provide engineering students with exposure to the technology-relevant business practices currently found in industry.
- Create an experiential environment where the two cohorts must learn each other's languages and mindset, in order to be successful.

Actions

To undertake these objectives the Schools of Business and Engineering did the following:

The Executive Associate Deans of both Business and Engineering, the Capstone Coordinator for Engineering, and selected course instructors for the Management Department's Entrepreneurship program met in the summer prior to the start of the 2016-17 academic year. We mutually agreed that both capstone programs needed improvement. In engineering, the Sternheimer awards were successful in providing project funding, but only superficially addressed business aspects of projects. In

business, the proposed senior entrepreneurship projects were generally directed at poorly founded ideas based on incremental innovations. We all agreed that a "merger" should provide substantial benefit to all sides.

Based on this administrative approval, the authors coordinated an experimental pilot program in August of 2016. We immediately decided to use a subset of engineering projects as candidates for inclusion in the entrepreneurships program. Engineering project criteria were: (1) Project goal was a new product; (2) Project particulars were understandable to both parties; (3) Team members and faculty advisors needed to be positive and resilient; and (4) It could not be a funded, industrially sponsored-project.

An early issue addressed was intellectual property. A draft "Letter of Intent" was crafted to provide a framework to develop business and engineering IP, which would belong to an anticipated joint entity. This assured that participating students be bound by the LOI to remove financial incentive for leaving a project upon graduation, and to reward long-term participation.

Teams from both sides were instructed to arrange meetings with their counterparts on a regular basis. This time was to be used to communicate progress and inform the other side of any issues or downsides.

Entrepreneurship students used these meetings to clarify specifications and general objectives of the engineering concepts. Over the course of the year, they also conducted research regarding substitute products, competitors, industry, market, and financial requirements. At various points in the fall and spring semesters, write-ups were provided for each of these areas to their respective engineering teams, in order to present findings and further communicate any issues, concerns, and potential opportunities to alter concepts. For the first time, the business students on each team were also required to prepare a poster for exhibition alongside the engineering posters at the Capstone Design EXPO (occurring April 28, 2017). The entrepreneurship students also gave oral presentations to EXPO judges, who consisted of faculty, industry experts, and business leaders gathered by both the engineering and entrepreneurship programs.

Engineering timelines and deliverables remained essentially unchanged for each of the two semesters. The Fall Semester deliverables included project brief, biweekly report and conference with faculty advisor (and outside sponsor), Engineering Design Specifications (EDS), prior art (patent & literature) search, interim project report and initial prototype.

For the spring semester, similarly required deliverables included bi-weekly reports and conferences with faculty advisors (and outside sponsors), societal impact reports, proof of concept prototypes and testing protocols, regulatory/environmental/safety/or financial reports (as defined by department), team final project reports, and EXPO participation (including poster, prototype and oral presentations to judges and others).

Initial Results

Starting in the 2016-17 academic year, twelve projects were identified for collaboration between the two schools. It rapidly became apparent that, despite an excellent communications channel between principal faculty in both Business and Engineering, this did not automatically transfer to faculty project advisors, business faculty, or the students. Students exhibited a remarkable reluctance to establish communication with their counterparts. This led to only a few excellent collaborative capstone projects, and several substandard project outcomes.

Two projects (out of 12) were considered a success as they were taken commercial by an interdisciplinary subset of the student teams. One project was driven by a business graduate, while the other was led by an engineering student with entrepreneurship graduates rounding out the team. Six teams reached a satisfactory conclusion, marked by passing hurdles set by Business with outside entrepreneurs and industrial partners. THe results of four teams were unsatisfactory due to poor communication, caused by reluctance of the two cohorts to interact with their counterparts. One clear signal of poorly performing joint engineering / business teams was the lack of synergy between the engineering and business posters at the year-end EXPO, embarrassingly obvious as the business and engineering posters were collocated.

For the 2017-18 academic year, ten engineering projects were chosen for the program. Key were increased emphasis on direct and frequent participation in project meetings by both cohorts, attendance by engineering faculty at business review presentations and sharing of interim reviews by both groups. Interim student grades reflected the improvement.

This report is being submitted just prior to the end of the 2017-18 academic year, so results are not final; however, there are clear trends, which are illustrated in Table 1. First, the enforced communication between the cohorts appears to have an effect: in the first year of the experiment, 33% of the collaborations had a poor outcome, which improved to 20% for the second year of the program. Another contributing factor appears to be

Table 1. Outcomes of Engineering / Business Collaborative Teams

Outcome	AY 16-17	AY 17-18
Outstanding – Spun Out Ventures	2	TBD
Good – Excellent Communication, Posters Complimentary	6	8
Poor – Inadequate Communication, Posters not in alignment or missing, failed course	4	2
Total Projects	12	10

the buy-in (or lack of buy-in) on the part of the engineering faculty to the collaboration concept. Great care was taken in the 2017-18 academic year to assure the engineering faculty advisors were committed to the success of the program. (In business, there is only one principal faculty member – this paper's co-author).

Conclusions

The first year of a project collaboration between VCU Engineering and the Business School's Entrepreneurship program was a qualified success. Two out of twelve projects continued as ventures staffed by the graduating seniors who worked on the projects during the school year. This was offset by four instances of poor inter-team communication, apparently caused by reluctance of the disciplines to effectively interact. This conclusion was noted by the authors, and was especially evident during the EXPO, where there were obvious differences and disconnects between the engineering and business posters, along with discordante information communicated by the cohort members.

For 2017-18 the authors conducted much more rigorus oversight of the student teams, with faculty follow-up regarding meetings, communication and collaboration, which grew buy-in of participating engineering faculty. We are confident that improved outcomes will be observed at the upcoming EXPO in April 2018.

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