Transcending the Silos: Leveraging Industry and Health Science Sponsored Capstone Project to Foster a Real World Learning Experience across the School of Engineering

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Capstone Design programs are being transformed from internally focused, research oriented projects to those engaging externally mentored projects from industry, health science and non-profit entities. This connection provides future engineering graduates the opportunity to interact with practicing engineers and other professionals to address real problems or opportunities. At VCU, capstone directors with extensive industrial experience are leading this effort. The previous departmental focused structure of capstone courses is being transitioned to a school-wide collaborative program to enhance student capstone experiences. This effort began with benchmarking regional peer institutions and comparison with current internal practices. The initial transition steps included a) formation of an active, school-wide steering committee, b) establishing project vetting procedures, c) support for core project guidelines, and d) standardized time lines for capstone course deliverables. These approaches have yielded a more robust capstone program, increased sponsorship, and mentoring by practicing professionals from industry, health science and non-profits. Students from different disciplines can participate in projects requiring multiple skills. The resulting program and project improvements are described in this paper. In addition, difficulties encountered in this transition process are described along with expectations for future enhancements.

Keywords: capstone, industrial projects, multidisciplinary, fundraising

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Introduction

The Senior Capstone Design courses in the School of Engineering at Virginia Commonwealth University are intended to demonstrate skills learned in a student's undergraduate education. The courses present students with the challenge of operating in a team to address open-ended, real-world engineering problems[1-2]. The VCU School of Engineering departments include Biomedical, Chemical and Life Sciences, Electrical and Computer, Mechanical and Nuclear Engineering, plus Computer Science. As guided by ABET accreditation criteria[3], the capstone experience should demonstrate skills relating to expectations[4] of employers recruiting BS engineering graduates and also skills for further graduate education.

By engaging industrial companies, non-profit entities, and the five health science schools on the VCUHealth (medical) campus regarding their unmet needs, the real-world aspects[5] of capstone projects can be addressed. Student teams actively engage in engineering design and development through stages of: problem definition, specification of function and performance requirements, conceptualization/ideation, analysis of options, working within defined constraints, identification and assessment of risks, mitigation steps, prototype development, performance testing, and reporting. At the conclusion of the two semester courses, teams present their work to sponsors, mentors, faculty, other students and the general public at the Capstone Design Expo. In addition to project results, learning experiences include: teamwork, conflict resolution, communication skills development, awareness of sustainability and global societal factors[6].

Two increasingly important elements in a capstone design curriculum are: (1) emphasis on and creation of multidisciplinary teams[6] and (2) the growing percentage of sponsored and mentored projects[7]. Multidisciplinary teams can be defined in two contexts: a) teams comprised of engineering students from two or more departments or b) teams composed of students from engineering and non-engineering disciplines. In both cases, the literature indicates multidisciplinary student teams produce better solutions than mono-disciplinary teams[1]. Capstone design surveys confirm this trend from departmental (mono-disciplinary) teams to multidisciplinary teams[8-10]. However, the traditional structure of departments within schools or colleges often inhibits the formation and grading of multidisciplinary teams and their projects. Typical issues arising from this "silo" structure include

separate standards for project generation, vetting methods, autonomous curricula, faculty expectations, and different timelines for project deliverables. This situation is exacerbated when seeking to develop multidisciplinary teams from across a university. Obstacles, such as intellectual property issues, exist with industry sponsored projects, but they may not be as formidable as those impeding multidisciplinary capstone teams. "Historical" knowledge on methods in conducting the capstone can require considerable effort to address. Top-down support from deans and collaboration faculty is required to successfully implement this approach[6].

Industry involvement may often provide more tangible benefit than instructor-generated projects. Projects suggested by industry focusing on unmet needs provide employers with trial interactions with potential future employees. Industry gains a low-cost approach for back-burner projects, strengthens its relationship with the university, and provides professional development for employees (as mentors). Undergraduate students benefit from participating in a corporate environment and dealing with practicing professionals. For the school, industry sponsors for the overall "capstone experience" can strengthen important connections with professionals and provide potential sources of expanded support.

Objectives

In 2013, the VCU School of Engineering made several priorities aimed at augmenting the students' capstone experience.

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

This led to the appointment of the authors which brought 60+ years of industrial, consumer, and medical product development experience to the faculty. As such, the approach to renewing the capstone program is rooted in the industrial best practices of engineering design and development. In addition, the VCUHealth complex, located on an adjacent campus, provides expanded opportunities between engineering and multiple health science disciplines.

Actions

The following action items were identified:

- Improve interdepartmental communications and provide administrative assistance on methods.
- Identify internal and external best practices, recommend and implement across departments as appropriate.
- Initiate targeted, minor curriculum changes to begin alignment of the five Engineering departments.
- Develop and execute a campaign to identify, solicit and recruit capstone sponsorship and unmet needs.

Benchmarking was conducted at regional institutions (Georgia Tech, NC State and Virginia Tech) and among the five VCU engineering departments. External benchmarking showed that about 50% of capstone projects are industrially sponsored. Capstone project budgets were $1,000 per team at most institutions and industrial sponsors typically provided support donations of $3,000 to $10,000.

As participation with outside entities has grown, closer relationships with the university intellectual property management became increasingly necessary[11]. At this institution, undergraduate students retain (own) their own intellectual property (IP). When students learn of the expense and time of patent prosecution, they most often agree to licenses with the university or project mentor. Templates for non-disclosure agreements (NDAs), intellectual property assignment, publishing and indemnification were proposed[11].

Internal assessment on this issue indicated that more effective communication was needed for departments and young faculty in dealing with projects with industry, as was an unambiguous team funding mechanism. A key factor for a smooth working relationship is addressing IP issues with all entities very early in the project. Also standardization timelines and deliverables for project teams became much more apparent.

Benchmarking showed integration of administration and curriculum for capstone design was rare among departments. An exception was in university based "entrepreneurship track" curricula engaged in product development and entrepreneurship experiences.

Benchmarking led to a series of ideas and actions. First, a Capstone Steering Committee chaired by the school's Director of Project Outreach and Capstone Design was created and comprised of faculty from each department. The role of the Steering Committee was to:

- Develop coordinated timelines and guidelines for submitting proposals.
- Establish common base funding for projects plus a mechanism for providing additional funds to teams based on special requests and team presentations.
- Review all project proposals and match with faculty advisors.
- Recommend core project requirements consistent with departmental input and objectives.
- Implement curriculum changes and timelines that are mutually agreeable to the departments.
- Plan and participate in the Capstone Design Expo.

Implementation

Actions by the committee included:

- Guidelines – general guidelines were identified but implementation is still in-process across departments.
- Project vetting – committee members review all proposal projects for appropriateness in addressing criteria for capstone courses.
- Base funding – base budgets of $500 are established for each project. Teams are issued detailed information on purchasing procedures and an individual project charge code.
- Additional funding – two sources are available for up to $1,500 in supplemental funding. One is from an endowment for capstone and the other comes from a pool funded by contributions from sponsors. Both requires teams to write an initial request for specific funding, then make a presentation to the committee for approval. .
- A new capstone website was launched to provide information for all stakeholders. This includes: (1) listing of projects, sponsors and teams, (2) an archive of prior year's projects, (3) information for sponsors, faculty and the public, (4) information for students, including detailed project deliverables for seniors and upcoming candidate projects next year (for Juniors), and (5) guidelines for the Expo presentations. http://www.egr.vcu.edu/senior-capstone-design/home/)
- Expo planning – The committee plans and organizes the two day Capstone Expo for 80+ senior teams. Additional support is contributed by associated School staff. The first day is held in conjunction with the Dean's Society and School Foundation Board members, faculty and students. The second, Expo Day, features students, faculty, industry sponsors and the general public. This includes field trips from local middle schools, encouraging interest in engineering and STEM education.

Project timelines and deliverables were developed for each of the two semester capstone courses. For the Fall Semester courses:

- Project Brief / Scope.
- Biweekly report and conference with faculty advisor (and outside sponsor).
- Engineering Design Specifications (EDS).
- Prior Art (patent & literature) Search.
- Interim Project Report – Proposed Solution, Project Plan with Initial Prototype / Mock-up.

For the Spring Semester courses:

- Biweekly report and conference with faculty advisor (and outside sponsor) – continue.
- Societal Impact Report.
- Proof of Concept prototype and Testing Protocol.
- Regulatory, Environmental, Safety or Financial Report (defined by department).
- Team final Project Report.
- EXPO participation including poster, prototype and oral presentations to judges and interested attendees.

The Capstone Expo has been held at the Science Museum of Virginia and now due to growth it is held at the larger Siegel (basketball) Center.

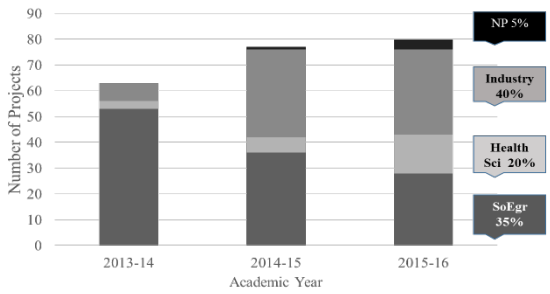
To increase the percentage of projects sponsored by Industry, Health Science and Non Profits the capstone leadership partnered with the VCU Engineering Foundation to coordinate the message, then identify, contact and call on prospective clients. Related engagement message points of fundraising and capstone participation were presented in a coherent fashion. At VCUHealth a directed introduction, familiarization and presentation program was designed and conducted to develop client departments and engage health science faculty mentors. Also, Richmond-area Non Profits were contacted working with VCU community outreach and industrial partners having existing community engagement presence.

Finally a "Capstone 101" faculty training program was developed and conducted aimed at Engineering faculty across all five departments. It was designed to familiarize key faculty with the basics of capstone design and changes in the program.

Results

During the 2013-14 academic year there were 63 projects in the capstone program from the five departments (Figure 1). Of these 15% were sponsored by entities

Figure 1: Growth of Overall Project Numbers and Diversity

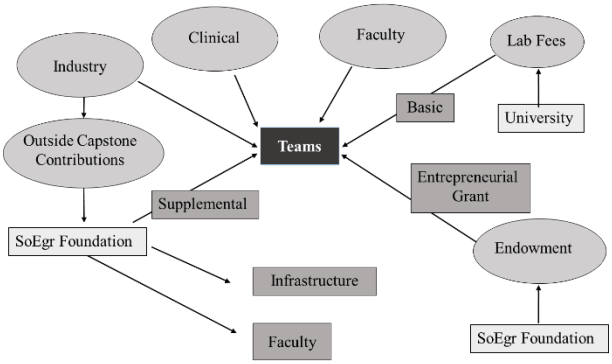


(industry, health sciences or non-profits) outside of the School of Engineering. As a result of the foundational changes made to the capstone program (specifically coordinating industry visits with fundraising activity, defining the treatment of IP and faculty training) the percentage of externally-sponsored projects increased in just two years to 65%. In addition, over the 2014-15 and 2015-16 periods 4 new non-profit, 4 new health science departments and 23 new industrial sponsors were established. This project diversity is illustrated by the new sponsors: The Virginia Home, Enrichmond Foundation, VCU Anesthesiology, Cardiology,

OB/GYN, and Surgery, as well as Boston Scientific, Tredegar, Pfizer, General Electric, Capital One, Willowtree Apps, QRC, Cranemasters, Anthem, QubecaAMF, Sealeze, Porvair Filtration, and Sentel Brilliant Innovations.

Another outcome was a four-fold increase in industrial contributions to the capstone program over the last 2 years. This, in turn, has led to a more robust, stable and better funded program. Figure 2 illustrates sources for

Figure 2: Team Funding Model



funding, which can support teams on four levels: basic funding from lab fees, supplemental funding from outside contributions, specific funding for equipment and entrepreneurial grants.

An indirect benefit of widening outside participation in capstone design is a two-fold increase in industrial participation in the School's career fairs and other job recruiting events. Industry-sponsored courses, such as one on process control technology, have blossomed. Donations to the Foundation's various giving levels have risen as well.

One area yet to respond is the goal of increasing the percentage of multidisciplinary projects, which has remained flat at 5%. This is attributed to the multiplicity of program due dates and deliverables currently required by the various departments. Improvement is expected as silos are reduced, with implementation of standardized timelines and other best practices.

Conclusions

Enhanced industrial and VCUHealth outreach, plus a clear IP handling policy has led to a 4-fold increase in externally sourced capstone projects. Collateral improvements in available project team budgets and overall industrial interactions have occurred. Awaited are improvements in the percentage of multidisciplinary projects, which await implementation of standardized timelines and other best practices.

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