ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #31993

Promoting Multidisciplinary Industry-Sponsored Capstone Projects

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Abstract:

Engineering design problems are intricate in nature and require not only skills that involve interdisciplinary education but also knowledge across disciplines. To promote and encourage multidisciplinary projects, the School of Science, Engineering, and Technology at Penn State Harrisburg has developed a model that facilitates the formation of teams to work on industry-sponsored capstone projects. These projects offer students invaluable educational benefits and help in preparing them for their future careers. This paper provides details about our approach to seek industry-sponsored projects and the process we follow to encourage students to become part of multidisciplinary teams that work on such projects. The paper also summarizes challenges and shares relevant information about the supervision and evaluation of team members and their final presentation and report.

Introduction

The most recent ABET general criteria states that engineering curricula must include a culminating major engineering design experience that incorporates appropriate engineering standards and multiple constraints [1]. The criteria also define a team as one that is working toward a common goal and should include individuals of diverse backgrounds, skills, or perspectives. As a result, multidisciplinary teams that address real-world complex problems are increasingly emphasized in capstone engineering courses [2-8]. Consequently, the capstone course has become a significant assessment tool in the ABET accreditation process. While the format and procedure of conducting capstone projects vary between programs and disciplines, such projects normally take two semesters to complete and in the majority of cases, students are organized in teams of three or more.

The computer science, engineering, and engineering technology curricula at Penn State Harrisburg include a capstone design project that allows students to use their problem solving skills and the technical knowledge they gain throughout their college experience to solve moderately complex problems by developing a device or system that meets certain specific requirements. This capstone experience offers students invaluable educational benefits and help in preparing them for their future careers. It also brings the analytical knowledge and practice in a hands-on meaningful project that involves product design, development, testing, and documenting. To promote and encourage multidisciplinary projects, the School of Science, Engineering, and Technology has developed a model that facilitates the formation of multidisciplinary teams to work on industry-sponsored projects. Such teams normally include computer science, engineering, and technology students. It is noteworthy to mention that multidisciplinary projects normally involve issues that require special attention. Such issues include forming qualified teams, evaluating team members, and coordinating project activities [9-15]. Another issue that we encounter is that while all engineering and technology programs have a sequence of two capstone courses, the computer science has a one semester capstone

course. While this presents a significant challenge in some cases, faculty and students always find reasonable ways to work around it.

The paper will provide details about our approach to seek industry-sponsored projects and the process we follow to encourage students to become part of multidisciplinary teams that work on such projects. The paper will also summarize challenges and share relevant information about the supervision and evaluation of team members and their final presentation and report.

An Approach that Facilitates Multidisciplinary Projects

The process of recruiting private companies, non-profits, other university units, and government entities to sponsor multidisciplinary capstone projects has evolved at Penn State Harrisburg over several years. Experience has shown that the most important first step is to demonstrate to these potential external partners "what's in it for them." Faculty connections with potential partners are crucial, but it is also important to have someone that can facilitate these connections. For example, in 2017 the School of Science, Engineering and Technology (SSET) at Penn State Harrisburg created a full-time position, known as the Industry Relations Coordinator, for the purpose of establishing and nurturing these connections, not only for graduate level research, but also for undergraduate capstone projects.

Leads for potential capstone sponsors can come from anywhere. For example, SSET uses:

- Representatives on various advisory boards for the school
- Contacts derived from campus Alumni Relations
- Discussions with employers at the SSET Career Fair
- Faculty research contacts
- Industry contacts from the school's extensive internship program
- Informal meetings between faculty and external representatives at conferences, etc.

These leads may be worked internally by an academic program or by the Industry Relations Coordinator (IRC). Early on, it is important to have appropriate faculty meet with representatives of the potential sponsors to explain the capstone program and describe the benefits to them. These benefits include: 1) The ability for Penn State students to work on a problem of value to the external entity that has been "back-burnered" due to lack of time and/or manpower; 2) An opportunity for the sponsor to observe the skill levels and work ethic of Penn State students engaged in engineering design, much like an internship – this can lead to better hires in the future; 3) The ability to build deeper connections with Penn State – capstones have led external sponsors to begin participating in other ways in the University mission, such as advisory boards, job fairs, and the internship program.

Once an external entity has agreed in principal to sponsor a capstone project, a timeline of events is set in motion. Ideally, this timeline looks something like this:

February: Sponsor submits a draft Capstone Project Request form[1]
Appropriate faculty review the Capstone Project Request for suitability as a capstone project[2]

March: Preliminary meeting with the sponsor to discuss elements of the Capstone Project Request[3]
Sponsor presentation to faculty and students is scheduled

April: Sponsor presentation to faculty and students, including Q&A[4]

May-August: Recruiting of students by faculty to work on the project

August: Additional sponsor presentations to faculty and students (as needed)

Fall semester begins and students commence work on the project

Note 1: This form was developed by SSET for the purpose of engaging potential project sponsors. It includes a description of the project, anticipated engineering disciplines needed, and an estimate of the student complement. In the student complement, the breakdown of the number of students needed from each discipline is proposed.

Note 2: In order to be a suitable capstone project, there are two very important elements that must be present: 1) There must be an element of engineering design (ABET); and 2) The project must be scoped appropriately for the amount of time (either one semester or two) that students have for capstone. Another important consideration is ensuring the student complement (disciplinary breakdown) is appropriate. For example, a civil engineering project may specify the need for an electrical engineer, when what the project really needs is an electrical contractor that knows the applicable codes.

Note 3: In addition to finalizing details of the Capstone Project Request and scheduling the sponsor presentation on campus, it is also important to identify a single engineer within the sponsoring organization who will be the project mentor and supervisor. Sponsors are encouraged to have the student team out to visit the workplace early on. In some cases, most or all of the work is done at the sponsor's site.

Note 4: The ideal audience for this presentation is juniors in various undergraduate engineering programs who will be registering for capstone in the Fall semester. Faculty involved in capstone as either instructors or mentors (technical advisors) should also be in attendance.

Sponsorship implies not only project supervision but also financial support. In SSET, this usually takes one of two forms:

- A single or ongoing gift from the sponsor to the University that can be used in a number of ways, including purchases and sponsoring of the Capstone Conference in May of each year. SSET has a small number of external entities that participate in this category
- An agreement to "pay as you go" for parts, supplies, software, etc. A number of external sponsors prefer to reimburse the University as needed for approved purchases.

Either way, SSET has set up levels of sponsorship to recognize sponsors at the Capstone Conference in May of each year. These levels are comprised of Friends of Penn State Harrisburg ($2500 or less), Bronze ($2500-$5000), Silver ($5000-$7500), Gold ($7500-$10,000), and Platinum (greater than $10,000). In general, $2,500 is committed to each sponsored project.

During the Fall and Spring semesters, it is incumbent upon faculty, sponsors, and students to work very closely together to ensure project success. Frequent meetings are encouraged. Some sponsors insist on design reviews. For example, during each Spring semester the Penn State College of Medicine (a regular sponsor) schedules meetings at the Harrisburg campus where multidisciplinary teams can come together to present their progress to the sponsor and other interested parties he/she has invited. This is an opportunity to ask tough questions of the students and it is a great learning experience for all involved.

Another important aspect of faculty and sponsor cooperation comes, at times, in adjusting the interdisciplinary student complement. For example, a student team comprising mechanical and electrical engineering students may begin developing designs for a sponsored product in the Fall semester, only to discover that in order to complete the project they need additional programming expertise from at least one computer science capstone student. At Penn State Harrisburg, the computer science students start their capstone experience in the Spring semester, so it is the perfect opportunity to request one of these students to join the pre-existing team.

Sample Multidisciplinary Projects

The following paragraphs briefly describe five multidisciplinary projects that illustrate the type of problems that students worked on in recent semesters.

Project 1: PC Wafer Loadout Vision Inspection System

This TE-sponsored project included students from mechanical engineering technology (MET), electrical engineering (EE), and computer science (CS). Students built a Multigig Wafer Vision Inspection system in order to increase the volume of inspected connectors by identifying incorrectly placed wafers assembled in the connector housing. In designing the system, the image recognition programming language is vital in accurately detecting incorrect connectors. The two programming languages considered where C and Python. The team consensus was to use Python as programming language. This decision was made due to the team's prior experience with Python and the use of OpenCV. In addition, the Python programming language is simplistic and easier to understand when troubleshooting.

The main challenge that students faced was due to the difference between the curricula of the three programs. Both MET and EE programs offer the capstone project course in two semesters (1 credit in the fall + 3 credits in the spring) while the CS program does not have the one credit course in the fall. Therefore, the MET and EE students worked alone on the design of system in the fall semester until the CS student joined the group in the spring.

Project 2: PLC Training Unit

This project was partially sponsored by Siemens. The goal was to develop a Programmable Logic Controller (PLC) trainer with several experiments for use in control system courses. The mechanical and electrical faculty of capstone project courses were able to recruit seven students from three different programs: two electrical, two mechanical, and three mechanical engineering technology students. The students were divided into two groups: 2 electrical + 1 mechanical (first group), and 3 technology + 1 mechanical (second group). The main objective of this

capstone project was to design a demonstration that utilizes the PLCs to perform simple tasks such as rotary motion, linear translation, and temperature control using industry standard devices such as relays, servomotors, and switches.

The long-term goal was to introduce the PLCs into the curriculum of several courses in these programs. Also, the students were asked to demonstrate basic capabilities of PLC driven systems and provide a manual that gives step-by-step instructions on how to use the software, PLCs, and execute the developed experiments. This would be used to create a learning tool for many classes to come, that may be used in a lab or classroom setting to demonstrate to future EE, EET, ME and MET students the practical and basic uses of PLCs.

Project 3: Developing a Portable Induction Heating System with Feedback Temperature Control

This Hershey Medical Center sponsored project included mechanical engineering and electrical engineering students. The team developed a portable radio-frequency induction heating system with a temperature control device using a commercially available induction power supply. The team used simulation driven product development to design an induction coil. The designed copper coil was 3D printed and the magnetic field produced by the coil was measured. Simulation and the experimental measurements followed a similar trend. Students also designed and developed a control system using NI USB-6009 and LabVIEW. The temperature measurements were performed using both fiberoptic and non-contact infrared temperature sensors. A precise temperature controller with a maximum temperature error of 2°C in the target temperature range of 50°C to 80°C was used.

The curriculum difference between the ME (3 credits in fall + 3 credits in spring) and EE (1 credit in fall + 3 credits) presented a huge challenge. The contribution from EE students in the fall semester was limited. ME students successfully simulated the magnetic field from different coils with some guidance from the instructor to keep the project on schedule. This served as a real-life learning experience for ME students as they had to learn new skills and implement them in a live project.

Project 4: Monitoring Human Movement in a Free Environment

This project was funded by the Smart Home Research Initiative at Penn State Harrisburg. The goal is to develop a low-cost wearable system to monitor movement and activity levels of elderly in free environment. Engineering students closely worked with the Kinesiology faculty member to determine the needs of the product. The student team consisted of three ME students and one EE student. In the fall semester, students designed and tested a system of multiple wearable sensors capable of determining the 3D locations and orientations of the trunk, extremities and calculating anatomical joint angles. Currently, the student team is working on refining the system and validating against the gold standard, marker-based motion capture system.

Students had a steep learning curve in familiarizing biomechanics terminology and relating them to the concepts learnt in the ME curriculum. Due to the curriculum differences, EE student involvement in the project started in the Spring semester and had to familiarize themselves with the project within a short time.

Conclusion

This paper described a structured approach to promoting multidisciplinary capstone projects. It also briefly described five sponsored projects that combined classroom learning and real-world applications, providing students with an invaluable experience. Sponsors were very pleased with the innovative solutions presented by students. Many sponsors expressed a desire to continue to strengthen their relationship with Penn State Harrisburg through future projects.

The paper also discussed challenges that multidisciplinary projects present. As we move forward, our goal is to intensify our efforts to strengthen our relationship with industry and the community. The more we strengthen these relationships, the better we are able to provide our students with opportunities that allow them to increase their technical knowledge and improve their social and interpersonal skills through working with individuals of diverse backgrounds and experiences. Students are required to present their projects at the annual School Capstone Design Conference held in May of each year. The conference has been a great opportunity to showcase our student and faculty expertise and to strengthen our relations with industry and the community.

Acknowledgement

The authors wish to thank the sponsors of the projects listed in this paper: TE Connectivity, Penn state College of Medicine and the Milton S. Hershey Medical Center, Masonic Village, Siemens, and the Smart Home Research Initiative. We extend our thanks also to faculty advisors in the various programs in the School for their support of the student teams. Finally, thanks to Laurie Hedlund, Industry Coordinator in the School of Science, Engineering, and Technology for organizing the industry presentations each fall.

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