Industrial Sponsor Perspective On Leveraging Capstone Design Projects To Enhance Their Business

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ABSTRACT

Capstone design projects have become commonplace among engineering and engineering technology programs. These projects are valuable tools when assessing students, as they require students to work in teams, communicate effectively, and demonstrate technical competency. The use of industrial sponsors enhances these projects by giving these projects more of a "real world" feel. Most of the research into capstone design projects focuses on student learning as well as the overall design process. However, very little research has been performed from the perspective of the industrial sponsor. In this paper, an industrial sponsor who has sponsored several large-scale capstone design projects presents their perspective on working with students on these projects. These projects serve as training systems for their existing employees and clients, and offer the sponsor the opportunity to evaluate the students as prospective future employees.

Keywords: Capstone Project; Industry Sponsor; Training Systems

1. INTRODUCTION

Over the past several decades, capstone design projects have become commonplace in engineering and engineering technology curricula (see Dutson (1997), Behdinan (2015), and Todd (1995), for example). As indicated by Allenstein (2013), survey results indicated a strong contribution from the capstone design course amongst alumni in the areas of:

- Recognizing the need for and engaging in lifelong learning
- Functioning on a multidisciplinary team
- Communicating effectively both orally and in writing, and
- Managing an engineering project

Projects may be developed internally, or may be externally sponsored. Often, academic programs wish to have external sponsorship of capstone projects, for a variety of reasons:

- External sponsors will provide students with a real-world problem to solve
- External sponsors will often provide financial support for both the project and the school
- External sponsors may become more invested in the academic program and more willing to serve on industrial advisory boards, and
- External sponsors may be more likely to hire program graduates that have demonstrated strong technical and professional skills on the project

Working with an industrial sponsor to ensure successful completion of a capstone project requires a strong commitment by the students or towards the students. This includes both technical design as well as "soft skills". Stanfill, et al (2014) presented a resource for students to effectively function on industry-sponsored project teams. It covers many of the soft skills students need, including project management tools, professional conduct expectations, and intellectual property.

However, a strong, externally-sponsored, capstone design project also requires a committed industrial partner to provide technical guidance, work with the faculty advisor to ensure the project remains on schedule, and provide financial resources as necessary to ensure that projects are constructed using industry-standard parts. Often, what separates a marginal or failed project from an outstanding project is the involvement of the industry sponsor. Yet the literature tends to focus more on the students than on the industrial sponsor.

Pezeshki and Beyerlein (2015) discussed coaching strategies for project sponsors. Their work is comprehensive in looking at course design and motivation for sponsorship, as well as potential pitfalls in working with various sponsors. They also present a client assessment rubric with four factors of performance:

- Project motivation
- Professional experience
- Interaction ability, and
- Institutional design process

These factors are an appropriate way of determining whether a potential sponsor would be appropriate for a particular capstone design project. Ford and Lasher (2004) also discuss working with industrial sponsors. They discuss guidelines that are presented to industrial sponsors, covering topics such as intellectual property, providing an advisor, and support of project costs. Their experience has shown that companies that donate funds to a project "tend to devote more time and effort to the project".

The focus of this paper is to look at large-scale capstone design projects from the perspective of an industrial sponsor with several years of sponsorship. The underlying questions to be answered are:

- What constitutes an appropriate capstone design project?
- What does the industrial sponsor look for from the academic program when sponsoring a capstone design project?
- What benefits are accrued by the industrial sponsor in supporting these projects?
- What should academic programs consider when approaching industrial sponsors with ideas for capstone design projects?
- How is the industrial sponsor's organization structured to support these efforts?
- How does the industrial sponsor see these projects evolving?

2. BACKGROUND

Penn State Behrend's School of Engineering offers ten baccalaureate degrees, two associate degrees, nine certificates and one graduate degree. Engineering degrees include Electrical, Mechanical, Computer, Software and Industrial Engineering, along with Computer Science. Engineering technology degrees include Electrical and Computer, Mechanical, and Plastics Engineering Technology. The tenth program is an Interdisciplinary Business with Engineering Studies degree that is housed within the Sam & Irene Black School of Business but includes significant coursework within the School of Engineering. The School employs 63 full-time faculty members and has 1470 undergraduate students. All of the baccalaureate degree programs require a capstone experience for graduation. In one program, this amounts to writing a research paper for a technical conference (e.g., Knepper (2004), and Gutman and Page (2002)). However, in most programs students apply a design process for an internally or externally-sponsored project. A general approach to the two-semester process is presented by Ford and Lasher (2004), although the engineering programs focus more heavily than engineering technology programs on design processes during the first semester, resulting in an in-class 3-credit course for engineering students versus a 1-credit course for engineering technology students. The course in the second semester of the project has no in-class component, with the emphasis on project implementation, test, and documentation.

Over the past several years, Process and Data Automation (PDA) has sponsored 14 capstone projects in the School of Engineering, with the majority of these projects involving students in Electrical and Computer Engineering Technology (ECET). The company is a full service industrial control systems integration firm. Their process control projects have ranged from water treatment facilities to ladder manufacturing. They handle all facets of industrial automation, from the turnkey automation of physical equipment and processes to the connection of plant floor equipment to associated business systems.

Recently, PDA moved their operations to within walking distance of the School of Engineering (see Figure 1). The new facility includes a high bay area that is designed for industrial processes, including an overhead crane, three-phase electrical power, and water access.

Figure 1. High Bay of the New Facility for Process and Data Automation

Sponsored Capstone Design Projects

One of the signature features of a PDA-sponsored capstone design project is its large scope. In each project that follows, students:

- Determined the sponsor/market needs,
- Developed requirement specifications,
- Created a design specification,
- Created appropriate drawings and schematic diagrams,
- Ordered materials,
- Constructed the system including:
  - Physical construction and/or framing,
  - Physical plumbing,
  - Electrical control panel wiring,
  - Electrical field device wiring,
- Tested the system for specification compliance,
- Communicated their progress and achievements in written and oral form to the sponsor and faculty members, and
- Presented their project to family and friends at a senior design conference at the end of the second semester

Figure 2 shows a Clean-in-Place (CIP) trainer. This trainer is used by PDA to test components from the field as well as to introduce new engineers to the CIP process. In the CIP process, three main cycles (pre-rinse, wash, and post-rinse) enable cleaning of all piping which may contain residual food, beverage or pharmaceutical products. The system uses Logix Batch and Sequence Manager (LBSM)[1]. The CIP trainer was designed to be taken apart easily, and this system was in fact disassembled and moved to the new location near the School of Engineering. Three ECET students worked on this project. Their effort included design and assembly of control panels, control of manipulated mechanisms, communications, and signal processing, along with creating a human-machine interface (HMI) for ease of operation. They also designed and fabricated the mechanical skid, and plumbed and wired the system.

Figure 3 is a photo of an automation flow trainer. The automation flow trainer includes three different types of flow meters along with three different types of flow limiting valves to help engineers learn about controlling each of these flow devices. Each meter and valve communicates to the Programmable Logic Controller (PLC) using a different set of signals. Three ECET students worked on this project as well. All electrical wiring, panel construction and plumbing were completed by the students, along with software development. The team additionally created a set of labs for using the trainer.

Figure 4 is a photo of a motor pump sizing project. This project was motivated by the desire of a faculty member teaching an electric machines course in the ECET program to have students expand their knowledge of electric machines to understand how to size a motor for a particular application. The system consists of three different size induction motors (0.75, 1.5 and 3.0hp), each coupled to an appropriate pump, along with three separate piping lines (1”, 2”, and 3”). Each motor is driven by its own adjustable speed drive. The piping rises to a height of 17 feet, creating an elevation head and friction resistance for the pumps to overcome. The purpose of the project is to have students in the electric machines course determine the appropriate pump and piping combination to ensure a certain flow rate through the piping and into a tank. Three Mechanical Engineering Technology (MET) students and one ECET student worked on this project. The MET students designed and constructed the entire mechanical system. The ECET student worked with PDA staff to complete the wiring schematic, software design of the PLC and Human Machine Interface (HMI), and panel wiring. Process and Data Automation provided significant financial as well as manpower support to the project because of the fact that there was only one ECET student on the project. The company was motivated to support this project, even though it was for use by engineering technology students, due to its potential as a training system for PDA and its constituents.

[1] See www.rockwellautomation.com

Figure 2. Clean-in-Place Trainer

Figure 3. Automation Flow Trainer

Figure 4. Motor Sizing Project

3. ROLE AND MOTIVATION OF PDA IN LARGE SCALE CAPSTONE DESIGN PROJECTS

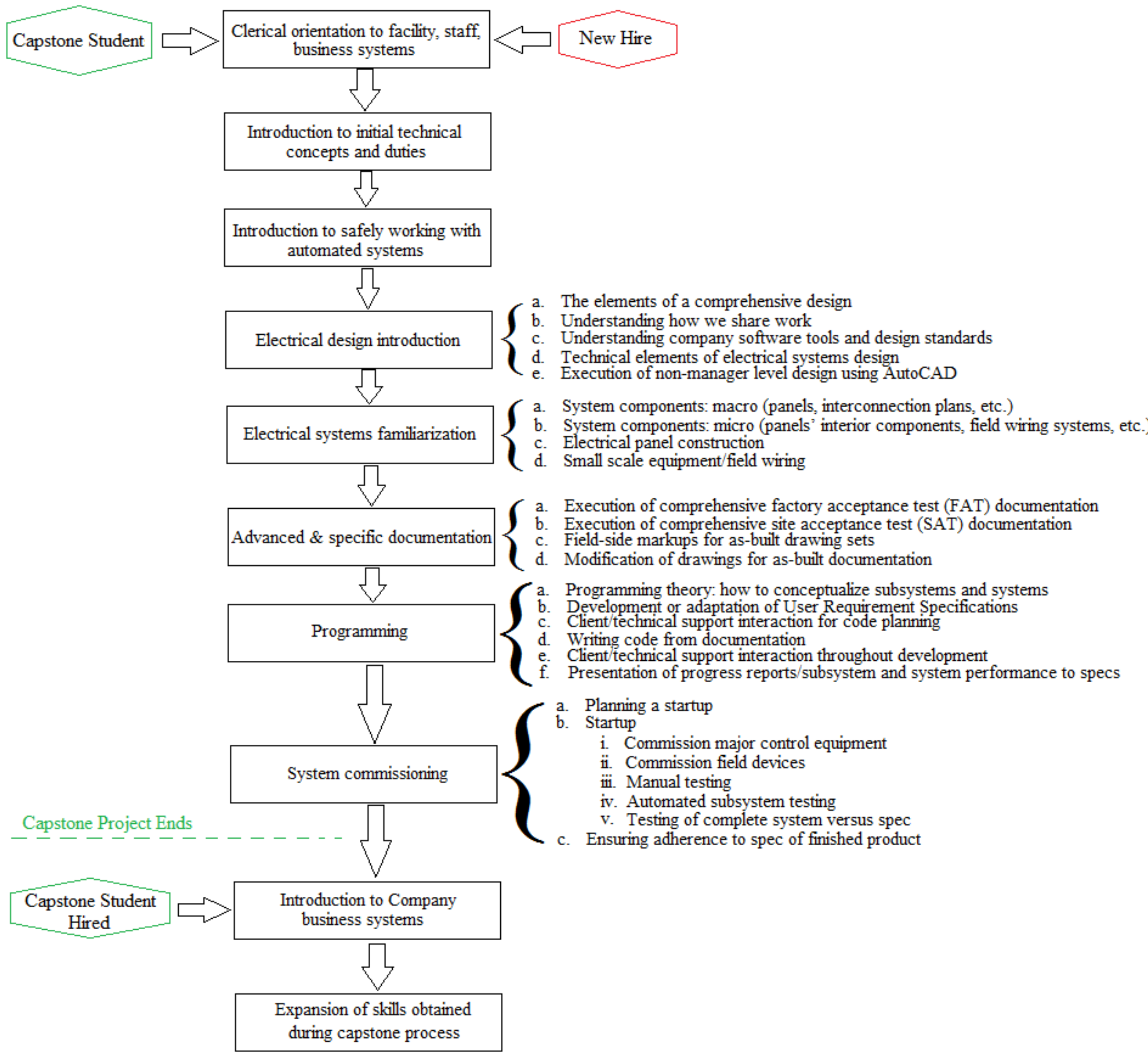
Process and Data Automation has made a strong commitment to capstone projects and by extension to undergraduate engineering education. Over the past several years, they have donated parts and services that are valued in excess of $100,000. And in the past year alone, they sponsored five capstone projects, indicating their continued commitment to the capstone experience. To understand their perspective, a number of questions were posed to the company. Their answers are as follows.

1. What constitutes an appropriate capstone design project?

We feel that it is important that the project provide both immediate and ongoing benefits to us as the sponsor. We want our employees to learn alongside the students who are executing the technical tasks of the project. Once complete, we want a tool or set of tools that will benefit our company as well as our clients.

Our business revolves around applying technical resources in the form of our people to solve real problems for clients. Ideally, we would always have client-provided projects that could be utilized to develop the initial skillset of new employees, which is presented in Figure 5. This would permit them to expand their skills and value in the most efficient manner. However, the real-world projects we work on are typically too complex for effective training of these recently hired engineers. We therefore look to leverage the capstone projects to *create* representative scenarios that provide the required training opportunities with the added benefit of evaluating students as prospective employees. Students working on the capstone design projects provide us with a large pool of such candidates. Those students that we eventually hire have already experienced the training that would typically be required of new employees but without the additional cost of training as shown in Figure 5.

Figure 5. Professional Development Process for New Hires at Process and Data Automation



2. What does the industrial sponsor look for from the academic program when sponsoring a capstone design project?

We sponsor projects with departments where we already have an established relationship, which gives us a good understanding of what students can and can't be expected to accomplish. We look for faculty to assist with drawing parallels between project needs and students' scholastic background and abilities. Functioning as an intermediary on items like documentation, labs, and reports is extremely helpful. This minimizes the amount of time that a sponsor is spending reviewing draft-level documentation. Occasionally students require a little extra motivation from the faculty advisor as well!

Our partnership with Penn State Behrend allows us to execute projects and retain any intellectual property created. This is key; what we build we can use immediately and in perpetuity if desired.

3. What benefits are accrued by the industrial sponsor in supporting these projects?

The immediate benefits for our employees are the development of skills that are normally obtained via field experience. They include:

- Experience with project management and administration. Not only are the projects used to challenge and stretch the skills of students, they are also used to introduce new concepts and responsibilities to existing employees in the form of supervisory skills as well as overall project planning and execution. More than a dozen company team members have benefitted within the role of Project Manager alone.
- Technical support for necessary and out-of-scope project deliverables, as well as tasks that are more labor-intensive than could be accomplished by the student team.

The ongoing benefits to existing employees include:

- All of our staff members, but especially junior staff members, obtain new skills working on these projects that make them more valuable and versatile to the company.
- In most cases the functional physical equipment at the end of the project can be used as-is, or through adaptation, for training at Process and Data Automation.
- Physical systems can be used to provide accelerated familiarization and ease of troubleshooting for equipment platforms that we have in the field.

Perhaps the largest benefit to our company comes in the Human Resources (HR) functions of evaluating potential staff and the accelerated pace at which successful candidates are financially valuable to the company.

4. What should academic programs consider when approaching industrial sponsors with ideas for capstone design projects?

There has to be a realistic mutual expectation of what student teams are going to accomplish in a given amount of time. As a general rule, a business should not expect to handoff their most technically imposing problems and/or provide little guidance and expect that a newly-formed team of students will deliver a "home run" on their first time out. The sponsor should be realistic and accepting of the volume and complexity of the eventual outcome. It is best if the sponsor can accept a prototype, a tool, or a concept or product to be expanded upon further as the end result of the project. Thus the student team is alleviated of the pressure to deliver a production-ready part or system via this type of project.

We are typically building miniaturized processing systems, often from a combination of new and used parts that we have available. These systems fit the needs of our business and clients well. Other industrial sponsors should consider the following: "what will teach the concepts of what we do, what will be useful long term, and what will help us to deeply evaluate potential staff members to do this work for us in the future?"

5. How are you structured to support these efforts?

While we utilize multiple staff members to manage each project (and thus obtain the previously mentioned benefits as project managers), we utilize a specific staff member in the role of electrical liaison for every project. He is a group leader for all electrical design as well as a mentor for student interns and entry level employees who work within his group. This dual responsibility has helped him to develop the skills required to get the most out of both new staff members and students in the capstone environment. He not only performs the electrical design oversight function but he is also able to create situations where students can succeed. This gives us the opportunity to evaluate them in a pre-hire situation much like we would post-hire, and has had an enormous impact on our total cost of human resources. We have maximized the likelihood of hiring appropriate staff, which lowers the time and cost associated with the recruiting process.

Our facility is helpful as well. A year and a half ago we moved to Penn State Behrend's Knowledge Park. This park is located directly adjacent to the school campus and it has allowed us to expand both our intern and capstone projects. Besides location, the facility is advantageous due to the presence of a high bay facility with approximately 24,000 square feet of open, quasi-manufacturing space including concrete floors with drains, ample electrical power, overhead crane, recessed truck dock, and other utilities. This facility has allowed us the chance to assemble more systems simultaneously, larger and more complex systems, and permanent equipment with oversight labs for software-specific projects.

6. How do you see these projects evolving?

As noted previously, our projects have evolved to take advantage of the Knowledge Park facility. No longer restricted to an office environment with applicable utilities, we have been able to raise the level of flexibility and complexity within the projects. We now create systems that we intend from the outset to provide a meaningful deliverable in the initial year but we always have an eye on what we can do to further expand in the future. Many of the systems now in operation will provide years of ongoing instruction both internally and within the capstone system.

To fully leverage the available flexibility, we have now begun engaging other engineering disciplines in our projects. This has aided us in creating more sound and agile mechanical designs while allowing electrical team members to focus on the project elements most specific to their training. Previously this would have required electrical students and/or additional company staff to perform these functions, often well outside of their areas of expertise. Now we can create multi-disciplinary project environments that more closely match the majority of real-world work examples that new engineers will encounter.

4. DISCUSSION

Process and Data Automation tries to leverage capstone projects on many levels. The projects they sponsor can be used for in-depth recruiting purposes, training their employees and clients to use specific equipment, help their more experienced employees hone their project management skills, and help their junior employees develop valuable troubleshooting skills that can be used in the field. For PDA, these capstone projects are synergized with their business model. They involve developing complex process control systems using PLCs which can also support professional development. An additional advantage of having their employees develop their skills on these capstone design projects is the opportunity to work and learn in a low-stress, low-risk environment.

An integral aspect of PDA's process for working with Penn State Behrend is to have an employee dedicated to both managing internships as well as being a dedicated technical resource for capstone design teams. The authors believe that this model could be replicated by other sponsors in a variety of industries.

To date, at least 10% of PDA's employees completed a PDA-sponsored capstone design project. The company has specifically stated that student performance on their capstone design project was the predominant factor in their being hired. Upon graduation, these students are able to "hit the ground running" for PDA.

5. CONCLUSION

Process and Data Automation has been able to use capstone design projects to further their business, with both immediate and ongoing benefits. The projects enhance both technical and project management skills in its employees. Capstone projects act as "on the job interviews" for students, and a number of PDA employees were hired based on their performance during their capstone project. The capstone projects themselves serve to give these future hires a head start in their training. Finally, the capstone projects help PDA and Penn State Behrend maintain a symbiotic relationship whereby students receive both strong theoretical foundations as well as strong experiential knowledge.

This paper demonstrates the basic approach PDA uses to leverage capstone design projects to the benefit of the company. Future work will look at how their approach fits within an educational framework.

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