

Small Business Sponsored Projects: Factors for Success

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The Mechanical Engineering Capstone Design sequence at Northeastern University expects students to produce a working prototype or component that satisfies a real world design problem. A recent successful project paired mechanical engineering students with the Alternative Fuel Foundation (AFF), a small non-profit bio-fuel reprocessor in Middleton, MA. The project required the students to develop a device to melt frozen fryer oil to aid the AFF in collecting used fryer oil from restaurants in the winter. This had to be accomplished with a strict budget of \$5000, safe operating requirements, and other constraints. The final project demonstrated a high level of integration of curriculum concepts on the part of the student team. The result was a fully functional device that satisfied the sponsor's needs at an affordable price. This project demonstrates how a small financial outlay by a company can lead to a large benefit for the company as well as a large educational benefit for the students.

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Introduction

The benefits of forging connections between capstone design experiences and industry are well known.¹ Industrial sponsors can provide both challenging projects and the financial and/or technical support to make them a reality. The involvement of industry experts keeps the projects current and relevant, and industrial advisors can provide a welcome perspective for assessment.² Frequent interaction between students and an industrial customer has been observed to provide definite learning benefits to the students, and in some cases appears to generate greater student commitment to the project.^{3,4}

Some highly advanced projects, such as those involving military robots or innovative medical equipment, are nearly impossible to achieve without the support of a large company. The Northeastern University (NEU) mechanical engineering capstone program has benefitted over the years from partnerships with Tyco International, Ltd., QinetiQ, Waters, INC, Harvard Medical School, and Johnson and Johnson, among others. Other authors have reported some very large financial outlays by large companies, which include support for hardware, equipment, and advisory support from the company.⁵ In surveying the literature on capstone-industrial relations, one finds many references to projects sponsored by large companies or professional societies, but fewer examples of projects from small businesses or non-profits.^{1,6}

Previous work by the authors has established grades, progression of the prototype, and positive jury comments as measures of success⁷. Data gathered since 2007 has shown an average grade of 3.86/4 for small

business projects, versus 3.76/4 for large business projects. Over the same period, the prototype score for small business projects averaged 7.25/10 for small business projects versus 5.78/10 for large business projects. In addition, 71% small business projects were rated as successful by the alumni jurors. Based on the preceding metrics there seems to be a small educational benefit to working with a small business.

With increasing emphasis in many universities on engineering entrepreneurship, it would seem that exposing students to small start-up businesses would be a valuable learning experience. In addition, many colleges are interested in promoting service learning among their student bodies. A capstone design project that involved working with a small non-profit company would seem to address both of these issues, provided the project contained sufficient challenge to allow the student team to demonstrate their engineering talents to a high degree.

The Capstone Design Sequence at NEU

The Mechanical Engineering department at Northeastern requires a two semester capstone design experience. During the first semester students form self selected design teams and are assigned to projects. Projects can be student proposed, faculty proposed, or industry sponsored. Accepted projects must contain the basic elements of design and not be purely experimental or purely analytical. Students work in self-selected teams of four to five members. Each team has a faculty advisor and an advisor from their industrial sponsor in the case of industry sponsored projects. The advisor's responsibility is to meet with the team regularly to provide guidance and critical oversight of the design

project. The goal of the first semester is to perform background research, including patent and market searches, and to develop design specifications and a final problem statement. Initial designs are also expected by the end of the first semester and are presented in written and oral reports.

In the second semester, the teams develop their final design. Teams are expected to do computational modeling and analysis as appropriate. It is expected that by the end of the term the teams will have constructed and tested a working prototype while considering economic factors, safety, reliability, maintenance (least number of parts), aesthetics, ease of assembly and deployment, packaging, ethics, and social impact in their design solutions. Students produce three written reports and three oral reports over the course of the term, as well as a technical poster and an executive summary. The final posters and presentations are evaluated by a jury of alumni and industrial partners. Grading is done by a committee consisting of all the faculty advisors along with a technical communication instructor. The grade depends in large part on how well they satisfy the specifications as well as the sophistication and technical validity of their design. Students are also graded on their written and oral communication, class participation, and project management skills.

Industry Relations with NEU Capstone

The Capstone course has seen a great deal of industrial support over the years. Northeastern has an extensive co-op program, where students have the opportunity to have 2-3 paid 6 month co-op experiences during their 5 year course of study. In some cases Northeastern students on co-op have forged connections that have lead to the employers proposing capstone projects. Other industry sponsored projects have been proposed by alumni of the program. In recent years 48% of the projects have been industry sponsored and of those 80% have been sponsored by non-profit, small or mid-size business concerns. Industrial sponsors typically contribute a \$5,000 grant to the program in addition to expensive components that are needed to complete the project. The amount of financial support varies and is negotiated during the project development stage. Existing intellectual property is owned by the company. New intellectual property generated by the students and/or the industrial mentor is co-owned by NEU and the company. The students receive a prescribed 30% of licensing fees. Small companies tend to be more flexible in their intellectual property regulations than large companies. Several famous large engineering companies in the New England area that hire significant numbers of NEU co-ops are not capstone sponsors because of their rigid intellectual property regulations.

The Alternative Fuel Foundation Project

The specific project discussed in the current work was sponsored by the Alternative Fuel Foundation (AFF). The president and founder of AFF is a recent alumnus of the NEU Mechanical Engineering program and experienced with the current configuration of the capstone design program. AFF is a small non-profit organization that collects used fryer oil from restaurants in Massachusetts. This oil is then reprocessed into bio-fuel. The restaurants collect the oil in 55 gallon drums which are then emptied using a vacuum pump-fitted collection truck. In the winter months the oil, which contains a high amount of water, becomes too viscous to pump into the truck. This increases the time required for each stop, which adds to the cost of collection and reduces the ability of AFF to process the fuel economically. AFF proposed a project whereby the design team would develop a means to lower the viscosity of the oil-water mixture quickly in order to reduce the collection time to fifteen minutes or less per stop. AFF had a maximum budget of \$5000 for a standalone device carried on the truck, or \$5 per drum for a device that was to remain with the collection drums. In addition, any powered device had to be powered either from the truck or from a portable generator on the truck, and had to be operated by one person. The device had to operate safely in a harsh, wet winter environment. The student team working on this project was a self-selected team of five students, all of whom were mechanical engineers.

Project Challenges

The challenges for the students in this project were related to technology, safety, and affordability. The project statement as provided by AFF was relatively simple: reduce the viscosity of the oil to the point where it can be pumped into the truck. This seemingly simple statement led the student team to a series of design considerations such as:

- Should the device melt the frozen oil, or prevent it from freezing in the first place?
- What is the specific heat of the frozen oil, and how does that relate to the amount of power required?
- Should heating be combined with agitation in order to speed up the process?

These and other questions forced the students to carry out initial testing on sponsor-provided samples of the used fryer oil in order to determine its thermal properties. This was a valuable learning experience for the students, as they could not simply look up textbook values for their material, due to the large amount of variation in the different oil samples.

After initial testing and preliminary designs, the student team came up with a device, shown in Figure 1,

which consisted of four cartridge heaters attached to a fiberglass pole that could be used to both heat and stir the frozen oil. Extensive use of both CFD and stress analysis and feedback from the sponsor led to this design. The seeming simplicity of this design masked a very difficult safety problem. The students had to work with high voltage power supplies (220 V) to make and test their prototype. In addition, the final product had to function without posing a risk to the end user, AFF's truck driver. A prototype that was eventually destined for high volume production could have the safety verification performed at a later date or by the sponsoring company. In this case, the sponsor needed exactly one functioning device. The students had to undertake a great deal of research into materials and electrical safety protocols to develop a Safe Operating Procedure before they could even begin to test their prototype. The team encountered a fair amount of resistance from the course personnel, who were concerned about their safety and potential liability arising from the use of this project. The students were forced to defend their project much more strongly than some other groups, arguing that while they had every intention of producing a safe device, they were unable to control the behavior of the end user. By having the end user involved throughout the process, they were able to satisfy both the department's need for safety and the end user's needs for a functional project, without delivering an unverified device to an unsuspecting client.

Budgetary constraints on a student project, especially unrealistically low budgets for the complexity of the problem, often lead to either reduced expectations or less than perfect work-arounds. In this project, however, the budget restriction had a very desirable effect. The students had to follow a good design procedure. Instead of tinkering, they relied heavily on finite element analysis and computational fluid dynamics analyses in order to solve the problem as completely as possible on paper prior to purchasing any parts. One of the desired outcomes of the capstone design course is to 'use design methodologies and technical analysis to implement solutions'. In some cases, however, student groups fall into a trap of 'try this thing, then try this other thing' without sitting down to figure things out analytically first. While faculty advisors and the existing capstone purchasing procedure are meant to minimize this behavior, it is a constant struggle. This group, by virtue of their strict budget, did not have the luxury of building multiple prototypes. They therefore used the results of small scale experiments to the fullest. The results of these low cost experiments gave them good input for their FEA and CFD models, which led to them being able to generate and refine their designs quickly and cheaply. The final cost of the project, including generator, hardware, and electrical supply was

approximately \$3700, much less than the \$5000 budget limit. In addition, the students calculated that the reduction in stop time would increase AFF's profits by \$135 per day, and would allow the device to pay for itself in one month.

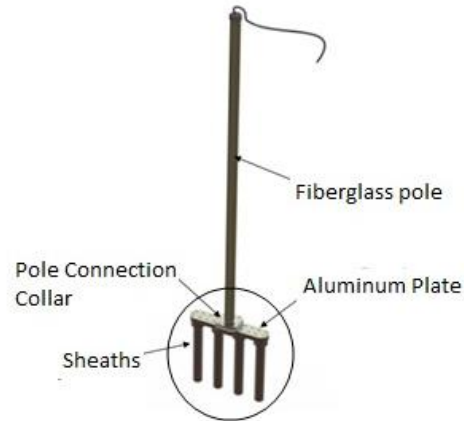


Figure 1: Final Design of Oil Heater⁸

Success Factors

This particular project worked for a number of reasons. The scale of the project was consistent with the time frame of the course. The project was self contained, and was not a component of a larger project at the sponsoring company. The sponsor was heavily invested in the project because the project was definitely needed. The sponsor was a recent graduate of the program. This meant less of a learning curve for the sponsor as to what the faculty expectations are and the time constraints regarding deadlines that the students must satisfy.

A key success factor that has been observed several times at NEU is that of sponsor expectations. Industrial sponsored projects tend to fail when there is a lack of communication of the sponsor's needs, when the problem is defined too narrowly or too broadly, or when the students and their industrial advisor cannot meet regularly. Projects sponsored by local companies have the advantage of allowing the students to see and talk with their industrial sponsor regularly. Well organized student groups are generally able to keep up with a more remote sponsor via electronic means, but poorly organized groups can end up leaving their industrial advisor out of the loop, leading to difficulties when they learn that what they are designing is not what the sponsor wanted.

Problems that are defined too narrowly can have unusual issues. In some cases an industrial sponsor has a device or application in mind that leaves very little room for group creativity. The problem arises when the course instructors, based on the syllabus and assessment tools, demand multiple initial designs and evaluation of

these designs. Students find themselves torn between trying to satisfy the industrial client and trying to satisfy course requirements, leading to stress and dissatisfaction among the students. If a project can really only have one possible outcome, due to the narrowness of the sponsor's specifications, the project may be highly successful from the sponsor's viewpoint, but lead to a demoralized, dissatisfied student team which also usually translates to a poor performance.

The AFF project avoided all of these major pitfalls. The company was located in Massachusetts, and was easily accessible by the students. Their project requirements were sufficiently broad to warrant creativity on their part, but at the same time the problem was not too nebulous for the students to grasp. The students ended up producing a sophisticated, multifaceted design which satisfied all the course requirements. Last but not least, it was the team members' drive, discipline, sense of responsibility and thirst for discovering uncharted territories that made this project a complete success.

Lessons Learned

The factors that led to the success of this project can be taken as a list of ideas to consider when vetting an industrial sponsored project.

A project must be of a self contained scale. Projects that are a small part of a much larger project tend to be less successful. The project must not be so narrowly defined as to remove all creativity nor so broad as to overwhelm the students. It is also helpful to have the project not be critical to a company's success. AFF gains a significant benefit from this project, however they would be able to function without it if they needed to.

Successful projects have industrial sponsors who are invested in the project, both financially and intellectually, and are willing to devote time to meeting with and mentoring the students. Students are more motivated with engaged sponsors with a demonstrated need and will generally work very hard to satisfy their requirements. In some cases, this includes late night sessions that often lead to unexpected co-owned intellectual property

The intellectual policies of the industrial sponsor also play an important role in a successful partnership. Small companies and non-profits are often less constrained in terms of sharing intellectual property. Student teams can feel hamstrung by the nondisclosure requirements in large companies, and sometimes come to the conclusion that they cannot discuss anything, which leads to conflicts with the course requirements.

Small to midsize companies tend to satisfy all these criteria for suitable projects. By making use of alumni and faculty connections, it is hoped that more small

business can be sought to partner with this successful program.

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