# Mechanical Engineering Technology Senior Projects – An Industry-Education Partnership

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## Abstract

At Penn State Erie, the Behrend College, Mechanical Engineering Technology (MET) seniors are required to successfully complete a senior design project for graduation. The vast majority of these projects are industrial based design and/or analysis projects which are sponsored by local and regional industries. They are part of a two semester capstone course for seniors. Typically two students and a faculty advisor are assigned to a project however more students may be part of a team for larger projects. A sponsoring industry pays a nominal fee to participate, and covers the costs for any materials that are needed to complete the project.

Both the students and the sponsoring industry benefit greatly from this experience. The students are exposed to industrial practices, and gain valuable experience which help them to find employment upon graduation. Sponsoring industries are able to take advantage of the program to get help with "back burner" projects that they do not have time for. They also get a pre-graduation look at potential employees. There are many examples of projects that have saved sponsors money through redesign of old products, or have given the industry an insight into factors associated with the design and development of new products. Additionally, the University benefits by exposing on campus resources to local and regional industry occasionally resulting in future funding for faculty research.

This paper outlines the industrially sponsored senior project program for MET students at Penn State Behrend. This includes the roles of the various participants in the project, the limitations placed on project scope, and most importantly, the responsibilities of the students. Examples are given of typical projects.

## Introduction

ABET requires that a mechanical engineering technology (MET) program must have some sort of capstone experience that pulls together various elements of the overall curriculum[1]. It must include both technical and non-technical problem solving skills. One of the more common ways of incorporating this type of experience into the program is to require some sort of design and/or analysis project as part of the capstone course(s).

Various methods have been used to devise such a project. Some schools create open ended projects designed to simulate real life scenarios[2]. Others try to incorporate competitive aspects into their projects by either having various groups work on the same project, or by entering one of the many design competitions available for students. A third approach is to use industrially sponsored projects.

Many people have written about open ended projects formulated by the course instructor. Hines and Christie [3] for example have used a project devised to address issues in the power industry. Most projects of this type attempt to simulate an industrial experience. Students must create schedules for their projects, work in teams, consider budget constraints, and apply technical knowledge to solving a design problem.

Competitive projects are also somewhat popular. Paulik and Krishnan [3], Beard [4] and Dwan, et al [5] have all used such projects. Edwards, et al[6] used a similar project in a junior level heat transfer project that could be expanded into a senior capstone project. This type of project tends to increase excitement for the project among students due to the competitive nature thereby motivating them to excel.

At Penn State Erie – The Behrend College (PSB) the School of Engineering and Engineering Technology has chosen to use industrially sponsored projects which have now been used at PSB for about two decades. Edwards and Forsman [7] reported on one such project involving analysis and testing of the air flow across a late model dirt track race car. Jackson [8] has taken this approach at Arizona State University East. This type of project subjects the student to direct contact with local industries giving the students a sense that their work will be meaningful. All of the engineering disciplines at PSB use industrially sponsored projects as part of their capstone experience, but each discipline handles the logistics a little differently. This paper reports only on the MET program.

## The Penn State Behrend MET Capstone Experience

The capstone experience is intended to provide the student with an opportunity to integrate their university education while bridging the gap between school and the "real world" – industry. At PSB, this is done by incorporating an industrial sponsored project as part of the experience. The overall experience involves a sequence of two courses taken in the fall and spring semesters for a total of 4 credits. The fall course is one credit with the remaining three credits for the spring course. Although the project is the foundation of the courses, there are other topics taught as well. The course lectures include important but often overlooked topics related to the practicing engineer such as social issues, economic issues, safety issues and ethical issues. Students are also exposed to project management including such topics as scheduling, budgeting and reporting. Communication and teamwork are stressed. Many of these skills are needed for the successful completion of the senior project. The nature of these projects requires the students to systematically complete their long-term project goals, so good planning is essential. The courses also include guidance in resume writing and interviewing skills.

One instructor is responsible for the overall course content and grading. Other faculty members are asked to serve as advisors on the project. Advisors are selected based, as much as possible,

on their research interests as they relate to the available projects. Iit does take additional effort by the faculty to make this a successful program. Fortunately, at PSB the industrially sponsored senior project program has been in existence for over 20 years, and has become ingrained in the teaching structure. Faculty has become accustomed to this additional load. A small amount of course relief is given for participating as a faculty advisor, but this does not reflect the amount of time involved in doing a good advising job. At a school that is just starting to use industrial projects it can be difficult to find faculty willing to put in the necessary time. One must look at the big picture, namely the benefits for everyone involved.

Several projects are usually available covering a wide range of interests. Students are assigned to one of the available projects based as much on their interests as possible. Students list their top two or three project choices from the list, and every effort is made to assign them to their number one selection whenever possible. One of the key concerns for selecting the right project is that the students should have a good opportunity for success. Bergman [9] has noted that students tend to get much more satisfaction from completing a relatively simple task as opposed to partially completing a very challenging task. Faculty advisors need to carefully scrutinize the project scope in the early stages to be sure that it is appropriate and can be accomplished.

## Benefits for the Participants

Industrially sponsored senior projects are well known to have many benefits for all of the participants [10][11][12].

Students develop their teaming and communication skills. They learn to schedule and manage a project. They find out that in industry it is important to stay focused and on task in order to complete projects on schedule. Contacts made by the students can help them in their search for employment, and the senior project is a nice addition to their resumes. Students at PSB often present their projects at various regional and national technical conferences sponsored by the American Society of Mechanical Engineers (ASME), Society of Automotive Engineers (SAE) and others. Some have gained recognition both regionally and nationally by winning awards at these conferences.

Sponsoring industries often are able to get someone to work on nagging “back burner” projects that are helpful to the company but that they never have time for at a very low cost to the industry. The projects must be appropriate for senior level students with little or no industrial experience and be able to be completed within the allotted time frame. These projects can be used by the company in recruiting since they get a pre-graduation look at students they may be considering hiring.

The faculty and the university can benefit through industrially sponsored capstone projects through the contacts made during a project. Occasionally these projects can lead to longer term research for the faculty resulting in the potential for grants, publications, and other scholarly activities. The university may learn of potential guest lecturers, specialized equipment the participating industry may have that may be available for use in a research project, or the potential for plant tours.

## Responsibilities of the Participants

Along with the many benefits come several responsibilities. While the students must plan and execute the project the other participants also must be aware that the students are not to be overused. The general rule of thumb is that each student can be expected to spend approximately 150 hours on the project. These hours will not be as productive as the same number of hours for a full time employee because the students are spending a lot of time learning as well as producing.

The primary responsibility of the students is to work diligently to successfully complete the project. At PSB students are given a very specific list of tasks that they are to accomplish each semester. Much of the work done during the fall semester involves learning about the project, learning about the sponsoring company, defining and planning the project, setting up project files, and reporting on the fall semester progress. Table 1 gives a list of specific tasks required during the fall semester.

**Fall Semester Tasks**

- Visit the sponsoring company and meet their representative
- Interview the representative to learn about the company history, products, etc.
- Take a plant tour (if possible)
- Decide on a project title
- Create an objective statement
- Create a scope and limitations statement
- Generate a list of specific goals which are agreed to by the sponsoring company
- Create a tentative schedule (Gantt Chart)
- Discuss confidentiality issues with the sponsor
- Create a project notebook
- Make a formal progress report at the end of the semester

Table 1

All deliverables must be discussed with the sponsor. The objective statement, scope and limitations statement, and specific goals are written into a formal document that must be signed by the students, advisor, and sponsor. Any other issues such as confidentiality agreements must be discussed with the sponsor, and any required formal documents must be signed.

The spring semester is when the students execute their plan. Since the spring semester course is three credits versus just one in the fall, this is when the students are expected to spend most of the time on the project. Sponsors need to be aware that they cannot expect much progress other than planning to take place in the fall. Table 2 shows the required tasks for the spring semester.

**Spring Semester Tasks**

- Meet weekly with the advisor for progress reports
- Meet occasionally with the sponsor as needed
- Complete all agreed upon work
- Complete all agreed upon documentation – usually minimal
- Make a formal final presentation at the year end design conference
- Make a formal final presentation at the sponsor if necessary

Table 2

Sponsors must be patient and willing to wait for answers. They must identify an engineering problem appropriate in scope for the team and time available. The complexity of the proposed project is critical. An experienced faculty advisor can help to guide this process. The sponsor is not required to have regular visits with the students, but must be willing to meet as necessary to answer questions and provide insight into the problem. The sponsoring industry is asked to provide a plant tour and company history during an early meeting. Any special expertise must be provided by the company. There is a nominal fee charged for the project. This fee is primarily used to help the students pay for the Fundamentals of Engineering Exam Fee. The company is also expected to pay for any parts or special test equipment. Company representatives are invited to attend the student presentations after each semester. Special arrangements can be made to make the final presentations at the company site if necessary.

Faculty advisors are key to the success of a project. One of the most important responsibilities of the advisor is to assure that the scope of the project falls within the capabilities of the students, and is doable within the available time. It is important to remember that the advisor does not do the project but only coaches and mentors. The advisor must meet with the students on a regular basis to assure that they stay focused and make reasonable progress consistently. There is a real temptation to step in and do the work if the students run into a problem, but the students will gain much more from getting through the problem themselves with only advice from the faculty. Faculty advisors also provide feedback to the course instructor to help with grading.

## End of Year Design Conference

At the end of the spring semester all of the student teams are required to make formal final presentations for their projects. All of the engineering disciplines make their presentations on the same day at the design conference. Invitees include the engineering department faculty and staff, the students' parents and friends, other engineering students, the sponsors' representative, university dignitaries, alumni, and the press. Presentations are made throughout the morning. After the presentations an invited keynote speaker addresses the group. Keynote speakers have come from both local and national companies such as Fisher Price, Chrysler, NASA, and many others. After the presentation by the keynote speaker there is an informal lunch and senior class pictures are taken of the students and faculty from each engineering discipline.

The purpose of this conference is to have something of a "gala" event for the students to present their work in a formal setting as opposed to just a final presentation for the faculty and sponsor.

It is a much anticipated annual event, and is very well attended. The seniors seem to really appreciate that this type of effort is made in order to showcase their projects.

## Other Issues

There are other issues inherent in this type of arrangement with industrial sponsors that may be of concern to any of the participants. Roth and Light [13] have written about some liability issues or other questions that may arise. Universities should consider these issues when setting up an industrially sponsored program. Here is a list of some of the questions that may arise. The reader is referred to the paper by Roth and Light [13] for answers to some of these questions and a deeper look at potential liability issues.

Questions students might have:

- Can students be held accountable for project results at a later time?
- Can "naïve" student reports cause an embarrassment to the students?
- What degree of expertise is expected of the students?
- Are student obligated to complete a certain amount of work?
- Will the scope change based on interim results?
- Will students be required to sign any intellectual property issue agreements that may cause future problems for the students?

Questions advisors might have:

- Can faculty advisors who are registered professional engineers be held accountable for results of student projects?
- Can the presence of a faculty advisor give a false impression to the sponsor that there is more expertise available on the project than actually exists?
- How can faculty afford to serve as an advisor when they already have a heavy workload?

Questions sponsors might have:

- How are proprietary issues handled?
- What are a university's rights in terms of publishing?
- What is the procedure for handling intellectual property rights?

If any of these questions or others come up in the early stages of a project they need to be immediately addressed. Agreements must be made between the university and the sponsor before work begins on the project.

## Examples of Projects

There are several general categories that projects tend to fall into including machine or product design, analysis, and investigation of design alternatives.

### Design Projects

Design projects tend to involve the design of test equipment for the sponsor. Product design is much less frequent. The design of test equipment involves not just the mechanical machine, but

also the controls. This is a perfect type of project for cross-disciplinary projects. Since the various disciplines have historically run their capstone experiences differently, cross-disciplinary projects have been somewhat rare. Recently several faculty advisors have begun to see the benefits of cross-disciplinary projects so they are becoming less rare.

A good example of this type of project was the design of an automatic test machine to test self retracting lifelines (SRL's). One machine was to be built to accommodate any SRL from 9 feet long to 175 feet long, and needed to be fully programmable to run any customer specified cycle. The project had in excess of 12 unique test parameters that were designed into the unit. Since a programmable controller was to be used to run the machine it was necessary to create a cross-disciplinary team involving both mechanical and electrical engineering technology students. A total of five students were assigned to this project – three MET's and two EET's. This was a very successful project, and the sponsor is expected to participate in the program in the future.

Analysis Projects

The MET students at PSB take several finite element courses and are usually fairly competent in that are by the time they are seniors. Most of the analysis projects involve a finite element analysis of an existing product. This analysis usually leads to recommendations for either further study or possible design enhancements. While the majority of these projects involve finite element analysis there have been a few that have involved CFD solutions to provide information for the sponsor.

One project involved both finite element and CFD analysis. A local company manufactures magnetic traps in a variety of sizes for removing metal particles from food products. The company was interested in learning about the stresses present in the trap components. Their customers were interested in the pressure drop that will occur across the trap to aid in the design of their piping systems. This company sponsored projects for two years to conduct a finite element analysis of the trap components and to develop reliable pressure drop information for their customers. The students were not familiar with the CFD software, so part of the project was to become familiar with the program. The finite element software was well know and understood by the sponsor, but the CFD software was new to them They needed to be convinced that the results were reasonable. Manual calculations produced results which were very close to those obtained from the software, giving the company confidence in the program.

Investigation of Design Alternatives

Industries are always looking for ways to improve their products. They may not have an urgent need for an improvement, but are always interested in cost saving enhancements. This type of project does not usually result in a direct design change for the sponsor, but provides the sponsor with valuable information they would have never had time to develop on their own. This information can be used by the sponsors for further product development.

A good example of this type of project involves a local manufacturer of rear view mirrors for large truck cabs. They had a nagging problem with road vibrations causing the mirror to vibrate

resulting in a blurred view from the mirror. The company found their own solution by stiffening the mirror to prevent vibrations, however, they wondered if going the other direction by softening the mounts to isolate the vibrations might work just as well at a lower cost. A student project team ran a series of vibration tests to determine the resonant frequencies for the mirror, mirror housing, and mirror support system. Various soft mount solutions were selected and tested by the team. From this work the team was able to make recommendations to the manufacturer for potential cost saving solutions to their vibration problem.

**Summary**:

Industrially sponsored senior projects which are part of the capstone experience for the students are a very good way to help the students to transition from the classroom to the workplace. These types of projects take a lot of effort on the part of the faculty and staff, but the overall results of using industrially sponsored projects at PSB have been very good and worth the effort.

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