Mechanical Engineering Technology Senior Projects – Partnering With Industry to Enhance the Students' Capstone Experience

by

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Abstract

The capstone experience for Mechanical Engineering Technology (MET) students at Penn State Erie, the Behrend College is comprised of a two semester sequence of courses. Part of the requirements for this course sequence is the successful completion of a senior design project. Most of these projects are sponsored by local and regional industries. The one credit fall course offering gets the students started on their projects. It is during this semester that the project is defined and planning is undertaken. The project plan is executed during the three credit spring course offering.

Incorporating this type of project into a capstone experience takes a lot of effort. Initially there has to be a lot of work put into finding sponsors for the projects, but eventually a pool of sponsors is developed which are willing to participate on a regular basis. It can also be difficult to find faculty members willing to put time into serving as advisors on the projects. Ideally the faculty advisor will be assigned to a project which matches his/her expertise. This is usually not too difficult unless there is a lack of content diversity in the available projects.

Sponsors are encouraged to supply students with "back burner" projects that would be helpful to the company but not critical. Sponsoring industries learn that this type of collaboration with the students has many positive aspects for the company. The university, faculty, and most importantly the students also benefit greatly from this type of experience.

This paper outlines some of the logistics involved in this type of project, benefits for all of the participants, responsibilities of the participants, potential problems or questions that may come up, and typical examples.

I. Introduction

This paper focuses on the capstone experience for Mechanical Engineering Technology (MET) students at Penn State Behrend. Other technology and engineering programs at Penn State Behrend incorporate a similar experience into their curriculums.

ABET requires that "capstone or other integrating experiences must draw together diverse elements of the curriculum and develop student competence in focusing both technical and non-technical skills in solving problems"[1]. This experience is designed in part to help prepare students to bridge the gap between academia and industry. Crain and Tull[2] have reported on a capstone course specifically designed to ease this transition. Key elements for such a course must include not only a technical design component, but also an emphasis on all of the other skills that are required for the successful completion of a project. Skills such as teaming, project management, ethical and social considerations, and others must be incorporated into the capstone experience.

Several types of projects have been used for this capstone experience at various universities. They can be generally categorized into three types: open ended projects devised by the instructor, design projects with some sort of competitive aspect, and industrially sponsored projects.

The literature abounds with examples of open ended projects devised by the instructor. Hines and Christie [3] report on a project devised to address issues in the power industry. Marshall, etal[4] have reported on the importance of having the students involved in such a project from the concept stage to the finished product, including an example of such a project. Mertz [5] talks about how such a project might be formulated by faculty members to simulate a real-life scenario. All of these types of projects are aimed at simulating an industry experience. Design specifications are drawn up. Students must create schedules for their projects, work in teams, consider budget constraints, and apply technical knowledge to solving a design problem.

Competitive projects do not seem to be as abundant as other types, but they have their supporters. Paulik and Krishnan [6] report on the evolution of a capstone course involving a competitive design project. Several advantages to this approach are listed in the paper including excitement for the project among students due to the competition, motivation to excel, and the simulation of the need to be conscience on deadlines during the design process. Both Beard [7] and Dwan, etal [8] have reported on successful competitive capstone design projects at their schools. The goals of this type of project are to increase the motivation of the student to succeed while attempting to simulate a real-life scenario.

Industrially sponsored projects have been around for decades, but seem to be gaining in popularity. The projects at Penn State Behrend usually fall in this category. Edwards and Forsman [9] reported on one such project involving analysis and testing of the air flow across a late model dirt track race car. Jackson [10] has taken this approach at Arizona State University East. This type of project subjects the student to direct contact with local industries. Students are working on real problems with the sense that their work will have meaning. The gap between academia and industry is beginning to be bridged while the students are still in school.

II. Why Bother?

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” that is industry. At Penn State Behrend, the mission of the capstone course is to provide the students with a valuable learning experience that integrates their university education with the many important lessons inherent in the industrial sector. This is done by incorporating an industrial sponsored project as part of the capstone course. The students are exposed to long-term project planning, the need for systematically completing long-term project goals, teamwork, and communication skills.

The industrially sponsored project is completed within the framework of a two-semester capstone course (total of 4 credits) taken during the student's senior year. The project is the centerpiece of the course; however, other important topics are covered in the lectures. These include important but often overlooked topics related to the practicing engineer such as social issues, economic issues, safety issues and ethical issues. Teaming skills and project management are important parts of the course. There is also guidance given in resume writing and interviewing skills.

A capstone course based on industrially sponsored projects places a lot of burden on the faculty to not only find the projects but to serve as mentors and advisors for the students. At Penn State Behrend the courses are structured with a course/program coordinator and a separate advisor for each project. The coordinator is responsible for the lectures, grading and overall program management. For the additional effort required beyond teaching the course, the coordinator is given credit for an added teaching load equivalent to approximately 25% of that for a three credit course. The project advisors are given credit for an added teaching load equivalent of approximately 17% of that for a three credit course. This is very low for the amount of effort required, so it can be difficult to find advisors. Fortunately, at Penn State Behrend 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, and they are expected to participate.

Despite the effort required to make this type of program a success there are great benefits to be derived from this type of project. Much has been written about these benefits for all of the participants [11][12][13][14][15], including the students, the sponsoring industry, the faculty, and the university. Here is a summary of some of those benefits.

- Benefits for Students

  There are many well recognized benefits for the students participating in this type of project. The students will receive a more rounded education by including an experience with industry. They are forced to develop their teaming skills and oral communication skills. They are exposed to the difficulties involved in defining real world problems and in meeting important deadlines. Additionally, the students make valuable contacts that may help them in finding future employment. Future employment opportunities for a student may also be enhanced by being able to list this experience on his/her resume.

  Annually there are several students who present their projects in oral or poster sessions at various regional and national technical conferences sponsored by the American Society of Mechanical Engineers (ASME), and other professional societies. Some have gained recognition both regionally and nationally by winning awards at these conferences.

- Benefits for Industry

  The sponsoring industry can also derive many benefits. The sponsoring industries are encouraged to provide the students with problems that can be successfully completed within the available time frame. These projects should be selected as appropriate for senior level students with little or no industrial experience. Most industries provide projects that are nagging "back-burner" projects which have the potential to provide valuable information to the company without risking a failure that could cause harm to the company. So the company gets the opportunity to have a group of students work on these projects that they may never have time to do themselves. These experiences can also be used by the company in recruiting since they get a pre-graduation look at students they may be considering hiring. In addition, sponsoring companies benefit indirectly by helping students to improve their education thereby enhancing the quality of graduates they may be considering for employment. Adams [16] offers a unique perspective of this type of industry-university collaboration from the perspective of the sponsoring industry. Adams is an industrial mentor for students from the Arizona State University in Tempe, Arizona. From his perspective these types of industrial sponsored student projects are valuable to the sponsoring industry. He has noted several problems the students have early in the project, such as teaming, project planning, and the ability of students to apply even basic engineering principles to complex problems. The students show much improvement in these areas as the project progresses giving them valuable new abilities for their transition from academic to industrial settings.

- Benefits for Faculty and University

  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 available for use in a research project, or the potential for plant tours.

III. Scope of the Project

The scope of the project is critical to the overall success of the capstone experience. Bergman [17] 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 to be sure it is appropriate and can be accomplished. Industrial sponsors need to be aware that these are not full time employees, and projects will take much longer to complete in this format. They need to have patience to wait for results.

One of the key deliverables for the first semester is a mutually agreed upon objective statement. The faculty advisor must scrutinize this document carefully to be sure that the project is substantial enough to qualify as a capstone project yet does not have unrealistic expectations for the students. In addition to an objective statement the students are required to generate a list of specific goals. If there are other goals that would be worthwhile to accomplish but might simply take to long, then they are listed under the heading “if time remains we will….”. The scope needs to take into consideration that these are undergraduate students, and that they are only expected to spend approximately 150 hours each working on the project. The size of the project team can be increased in certain cases to tackle a larger project. Under no circumstances are project teams expected to work on the project beyond the end of the semester regardless of the status of the project.

IV. Responsibilities of the Participants

The sponsoring company, the students, and the advisor all have a role to play and associated responsibilities to make this experience successful.

- <u>Responsibilities of the Sponsor</u>

  The sponsor must be willing to play an active role in the project. They must identify an engineering problem appropriate in scope for the team and time available. The complexity of the proposed project is critical. A guideline that is given to potential sponsors is that the project should attempt to expand the new information and technologies learned by the students beyond their normal course work by a reasonable and practical level. Experienced faculty advisors can help to guide this process. The sponsor will have to meet with the student team enough times to adequately familiarize them with the project and its general problems. It is asked that the sponsor provide a plant tour during an early meeting. Regular meetings with the company are not a required part of the project, but good communication is essential.

  The company is expected to provide any special expertise needed for the project. Their liaison needs to be available to answer any questions that may come up. An attempt is made to limit the need for this during the early planning stages, but occasional questions may arise.

  Since this is part of a required course for the students, university resources will be used as much as possible, including laboratory facilities, technician support, etc. The company is asked to make a nominal gift to the school for each project, and to supply any special physical resources. Physical resources might include such things as test parts or materials needed to build test equipment. The initial gift is used primarily to help the students pay for the Fundamentals of Engineering Exam Fee, and to help offset costs to send students to various conferences to present their work.

  Sponsor representatives are invited to the final presentation on campus. If they are unable to attend arrangements can be made to make a special presentation at the company.

- <u>Responsibilities of the Students</u>

  The primary responsibility of the students is to work diligently to successfully complete the project. Students are given a very specific list of tasks that they are to accomplish each semester as follows.

<u>During the fall semester the students must</u>:

- Become familiar with the sponsor – this is usually accomplished through an initial visit to the company. The purpose of this visit is to more to become familiar with the company than with specifics of the project. The students should be prepared to interview the liaisons about company history, number of employees, major product lines, market share, etc. This is usually the visit when the students get a plant tour. The project is also outlined at this time.
- Decide on a title for the project.
- Generate an objective statement.
- Generate scope and limitations.
- Generate specific goals in conjunction with the sponsor and the faculty advisor. These goals, along with the objective statement and scope and limitations are formalized in writing. This document must be agreed to by all parties. The document is signed by the students, sponsor, and advisor, and becomes the basis for much of the grade assigned for the project.
- Generate a project plan. The students are required to develop a Gantt chart for the project which identifies the major phases of solving/studying the project.
- Discuss deliverables with the sponsor so everyone is in agreement about what to expect as an outcome.
- Discuss confidentiality issues with the sponsor.
- Begin to conduct project meetings. The meetings are between the students and the faculty advisor. The schedule for these meetings is somewhat informal during the fall semester since the students are primarily in the planning stages, and not actually working on the technical aspects of the project.
- Create a team notebook. The notebook should be neat, concise, and maintained in a professional manner. Specific sections are required. Everything related to the project must be kept organized within the notebook.
- Make a formal progress review at the end of the fall semester. Formal oral presentations are made to the faculty as a whole. It is important at this point that the students demonstrate steady progress toward project completion. Much of the work at this point will be limited to planning. All planning must be complete at this point, and many groups report on some technical progress as well. The fall semester course is only one credit so it is expected that the bulk of the work will be done during the spring semester, which is a three credit course.

<u>During the spring semester the students must</u>:

- Have weekly meeting with their advisors. These meetings are to be conducted by the student team leader. The students are to create a “to do” list each meeting and report on the progress the next meeting. It is important for the students to demonstrate continual progress on the project.
- Have occasional meetings with the sponsor as required to keep the project on track and to make interim progress reports.
- Complete all of the agreed upon work.

- Create all agreed upon documentation.
- Make a formal final presentation of the students' work. At the end of each spring semester a design conference is held for these formal presentations. All engineering disciplines have their students presenting at this time. Any faculty member can attend the presentations and is asked to help assess them. Company sponsors are invited, along with parents, friends, and special guests. Freshman orientation classes are often required to attend to see what is coming at the end of their four years.

- Responsibilities of the Advisors

  Faculty advisors are very important 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 time limitations of the school year.

  The advisor should be a coach and mentor to the students. It is the advisors responsibility to keep the team focused and on track for a successful completion. The advisor may answer technical questions the students need to continue to make progress, or advise on the use of special software or test equipment. However, advisors must resist the temptation to do the work themselves. They are there to support and guide the students, not to do their work for them.

V. Examples of Projects

Flow Analysis of a Magnetic Trap

A local company manufactures magnetic traps in a variety of sizes for removing metal particles from food products. Customers are always 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 develop reliable pressure drop information for their customers. Each year a different size trap was analyzed using CFD software. The students were not familiar with the software, so part of the project was to become familiar with the program. They were required to build a solid model of each trap, import the model into the CFD program, and run enough different flow rates to create a curve which the company could use to determine the pressure drop. Since these traps are used for many different food items, a family of curves was created for each size trap. Students demonstrated that the method the company was using to determine these pressure drops in the past was producing incorrect information, so they were a little skeptical about the results. Manual calculations were used to verify the CFD model, and produced results which were very close to those obtained from the software. This gave the sponsoring company confidence in the program.

This is a good example of a project that resulted in information the company can use on a regular basis to satisfy a customer need. Additionally, as a result of this work the company already has plans for future project sponsorships.

Study of Vibration Suppression of Class 8 Truck Mirror

A local manufacturer of rear view mirrors for large truck cabs had a nagging problem with road, engine, and wind inputs causing the mirror to vibrate. This resulted 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.

This project is an excellent example of a type of project that does not 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.

SRL Automated Test Machine

The objective of this project was to design and build a functioning 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 custom 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.

This project is an excellent example of a very successful cross-disciplinary project. These types of projects are possible when the entire school of engineering and engineering technology requires similar industrial sponsored projects for all of its students.

VI. Liability Issues

Roth and Light [18] 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 summary of the issues reported in the paper by Roth and Light.

Can students be held accountable for project results at a later time?

It is recommended that formal documentation be held to a minimum, and that the university makes it clear to the sponsoring industry that they must verify any results generated by the students before using them. This is partially accomplished through a disclaimer signed by the sponsor.

Can "naïve" student reports cause an embarrassment to the students?

Again, it is recommended that formal documentation be held to a minimum. The scope of any deliverable documentation should be made clear early in the project. More extensive documentation should be produced under other arrangements with the university, and will most likely be handled by the faculty.

What degree of expertise is expected of the students?
Any specialized expertise must be supplied by the sponsor. A faculty advisor may have some expertise in the field, but is likely to lack the specialized knowledge of the sponsor. Students are expected to apply knowledge learned in previous courses, and to add to that knowledge by only a reasonable amount.

Are students obligated to complete a certain amount of work?
A well defined project scope should let the students know the amount of work they are responsible for. Failure to complete this work will affect their grades, but they are not responsible to complete any unfinished work after the completion of the course. Sponsoring companies should be made aware of this up front.

Will the scope change based on interim results?
The initial agreed to project scope should be the defining document. Any change in direction of the project based on interim results should be carefully reviewed by the advisor, and formally documented with the sponsor.

Will students be required to sign any intellectual property issue agreements that may cause future problems for the students?
Any confidentiality agreements signed by students or representatives of the university are binding. These should be carefully studied before signing.

Can faculty advisors who are registered professional engineers be held accountable for results of student projects?
Faculty advisors do not professionally stamp the project results nor do they perform the work, so are not liable for the work.

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?
The projects are conducted by the students, not the advisors. The advisors are available only as mentors, and therefore any expertise held by the advisor cannot be considered an available asset for the project.

How can faculty afford to serve as an advisor when they already have a heavy workload?
Students do the actual work, not the advisor. However, there is a large commitment from the faculty member for little recognition. The faculty advisor receives only a small relief from his/her teaching load. The ideal faculty advisor is more concerned with the student's education than his/her own workload.

How are proprietary information issues handled?
Proprietary issues must be addressed early in the projects. Any nondisclosure agreements must be carefully studied and signed before work begins. These documents are binding.

What are a university's rights in terms of publishing?

No results or recommendations will be published by the university without the consent of the sponsor. The sponsor has the right to review any information to be published, and has the right to remove any information they deem proprietary.

What is the procedure for handling intellectual property rights?
Formal agreements need to be recognized, generated, and signed between the sponsor and university defining how to deal with any patents, trade secrets, or other intellectual property involved in the project.

Should the company make important decisions based on project results?
The university should make it clear to the sponsor that any results are produced by non-professional engineering students and cannot be guaranteed accurate. Companies must verify results before using them for important decisions.

These are just some of the potential tough questions that may arise, and very brief recommended answers to the questions. Readers are directed to the paper by Roth and Light[18] for a more detailed discussion of these issues.

VII. Summary

Some sort of capstone design experience is required by ABET. Different universities approach this is different ways, one of them being through industrial sponsored projects. These projects can be difficult to incorporate for a variety of reasons including obtaining sponsors, finding the right faculty member to coordinate the capstone course(s), and motivating faculty to fully participate in the project as advisors. Liability issues need to be addressed up front. If these obstacles can be overcome there are great benefits to be derived by all of the participants. Most importantly the students gain a very good learning experience, exposure to industrial practices, and enhanced employment opportunities. Overall, it would seem to be worth the effort.

References

[1] "Criteria for Accrediting Engineering Technology Programs," ABET Technology Accreditation Commission, ABET, October, 2005.

[2] G.E. Crain, M.P. Tull, "A Capstone Course Targeting Industry Transition," Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, 2004.

[3] P.D. Hines, R.D. Christie, “A Capstone Design Project to Meet the Needs of the Changing Power Systems Industry and Satisfy New Accreditation Standards,” IEEE Transactions on Power Systems, vol. 17, no. 3, August, 2002.

[4] B. Marshal, M. Parker, T.L. Stewart “Senior Design Projects: A Design Example from Concept to Finished Product,” IECON’01, The 27th Annual Conference of the IEEE Industrial Electronics Society, 2001.

[5] R.L. Mertz, “A Capstone Design Course,” IEEE Transactions on Education, vol. 40, no. 1, February, 1997.

[6] M.J. Paulik, M. Krishnan, “A Competition-Motivated Capstone Design Course: The Result of a Fifteen-Year Evolution,” IEEE Transactions on Education, vol. 44, no. 1, February, 2001.

[7] R.W. Beard, “Robot Soccer: An Ideal Senior Design Experience,” Proceedings of the American Control Conference, Chicago, Il, June, 2000.

[8] T.E. Dwan, G.E. Piper, C.E. Wick, B.E. Bishop, “Systems Ball – A Creative Capstone Design Experience,” ASEE/IEEE Frontiers in Education Conference, 2001.

[9] R.C. Edwards, D. Forsman, “A Rapid Prototyping Application in Wind Tunnel Testing – A Student Project,” Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition, 2001.

[10] A.E. Jackson, “An Industry-Centered Capstone Experience for Aeronautical Management Technology Students at Arizona State University East,” ASEE/IEEE Frontiers in Education Conference, 1998.

[11] B. Darrow, “The Marriage of Industry and Academia,” Design News, vol. 44, no. 18, September 1988, pp. 22-23.

[12] J.G. Falcioni, “Industry and Academia Come Together,” Mechanical Engineering, vol. 118, no. 3, March 1996, p4.

[13] K. Beckman, “Closing the Industry-Academia Gap,” IEEE Software, vol. 14, no. 6, November 1997, p49-57.

[14] D.S. Bosley, “Collaborative Partnerships: Academic and Industry Working Together,” Technical Communications, vol. 42, no. 4, November 1995, p611-619.

[15] D.E. Roth, J. Bandstra, “Problem and Expectations of Industrial Sponsored Undergraduate Senior Engineering Technology Projects using FEA,” Proceedings of 1992 International ANSYS Conference, Pittsburgh, PA, pp 3.53-3.58, 1992.

[16] N.G. Adams, “Industry-University Collaboration on Under-Graduate Engineering Design Projects – An Industrial Mentor’s Perspective,” Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition, 2003.

[17] C.A. Bergman, “Senior Design Projects with Industry,” ASEE/IEEE Frontiers in Education Conference, 1998.

[18] D.E. Roth, R. Light, "Industrially-Sponsored Senior Projects – Answers to Tough Questions," Technology Interface, Fall 1998.