AC 2009-30: SENIOR DESIGN PROJECTS FOR ENGINEERING TECHNOLOGY: ISSUES, BENEFITS, AND TRADE-OFFS

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Capstone Projects for Engineering Technology: Issues, Benefits and Trade-offs

Abstract

Capstone courses in our engineering technology (ET) programs are structured as open-ended undertakings where students are expected to creatively analyze, synthesize, and apply a wide-variety of learning outcomes from prior coursework. A capstone project may either be industry-sponsored or internally-sourced with student teams advised by faculty and engineers from local companies. The team's goal is to meet the deliverables required by the proposal or statement of work. The semester culminates with a formal presentation of results evaluated by a professional panel of practitioners and a final report substantiating the results and findings.

Mechanical Engineering Technology (MET) seniors are tasked to solve multi-disciplinary problems based on a statement of work initiated by a sponsoring local company. Electronic Engineering Technology (EET) projects originate internally in the form of proposals developed jointly by students and faculty with the objective being to design, construct and test a prototype system.

A quality project requires faculty, sponsors and students to weigh a number of issues. Those that have no practical value or that merely serve the short term needs of an industry sponsor are not suitable. Another challenge is setting the scope of work and level of difficulty to be appropriate for ET seniors. Successful project management among the team members and their relationship to the faculty and external sponsors requires an array of communication and soft skills. Resources must be factored into the planning process: e.g. fabrication capabilities, technical support and/or the cost of purchased components/services. In small teaching institutions, the above issues are especially critical and must be carefully weighed.

This paper discusses the structure, approach and evolution of capstone projects within our College. It compares and contrasts the differences between industry-sponsored and internally-sourced projects. The elements of project structure, resource trade-offs and successful execution are addressed as well as the issues and benefits experienced by students, faculty and industry sponsors.

Introduction

Capstone project courses are a vital element in engineering technology (ET) programs. Since capstone courses are integrating experiences and appear prominently in assessment plans, successful programs are highly dependent on the resulting performance of students. Efforts to improve capstone quality have been the subject of much work in recent years. The primary motivations behind capstone improvements are: increasing industry relevance, showcasing graduate skills and the desire of faculty to adopt new best practices. However, it has been observed that too often students lack the necessary creativity, initiative and ability to develop robust solutions. Some have addressed this issue by developing innovative laboratory structures throughout the curriculum that better prepare seniors for the challenge[1]. Others have sought to connect students with local industry either prior to or during the capstone project[2-8].

The quest for improvement has lead to two fundamentally different approaches: industry-sponsored and internally-sourced projects. Within our programs, both are being employed. In addition, the capstone framework may be design-based and/or test-oriented. This paper discusses the recent history and experiences within Mechanical Engineering Technology (MET) and Electronic Engineering Technology (EET). Benefits and trade-offs are compared and contrasted, and the preferences that may make one approach more advantageous than another are discussed.

An organizational entity within the College relevant to capstones is the Engineering Application Center (EAC). The EAC is chartered to work directly with industry on projects that involve faculty and students. The role of the EAC is to contact local industry to ascertain interest in sponsoring capstones. The MET program currently employs the EAC in this capacity. For a typical industry sponsor, the process involves a visit to the campus, meeting with the faculty and a tour of the facilities. At the meeting, the specific interests and capabilities of the sponsor and faculty are discussed. Subsequently, sponsors generate statements of work and identify representatives to serve as points of contact for the teams. The above preparations are completed prior to the capstone semester so work can begin immediately. At the start of the semester, projects are assigned based on team interest, and an onsite visit to each sponsor is arranged. For projects to be successful, a lot of preparatory work must be done early on.

Comparing and Contrasting Capstones

An examination of MET and EET capstones reveals five points of contrast: 1) project sourcing, 2) type, 3) interim feedback and evaluation, 4) final assessment and 5) supplemental resources. Project sourcing from industry sponsors began four years ago within the MET program. Prior to this, proposals originated internally, either by the faculty, the student teams or in collaboration. However, within the EET program, projects have been and continue to be internally-sourced.

Capstones types may be design-based or test-oriented. The objective of a design effort is to produce a working prototype while the objective of a test project is to plan, test, analyze and interpret results. Within the MET program, both types of projects have been successfully undertaken. Capstones within the EET program are exclusively design-oriented, a long standing custom due in part to the lack of industry-grade measurement equipment. It is interesting to note the above project sourcing preferences are also found in the mechanical and electrical programs within our College.

The third point of contrast is the interim feedback and evaluation method. In MET capstones, students deliver weekly oral presentations, time sheets and written reports that: 1) act as a catalyst for structure and organization, 2) report status, issues and next steps, 3) improve slide content and oral presentation skills, 4) strengthen team skills and 5) engender cross-project critique and sharing of ideas. In addition, industry sponsors are invited to attend these weekly review sessions. EET capstones require similar written reports; however, there are fewer and less robust oral presentations. Since the projects are internally-sourced, weekly review sessions consist of the course instructor and the teams.

The fourth point of comparison involves final assessment. MET capstones end with a symposium where teams deliver an oral presentation to an audience of faculty, students, and a panel of judges composed of practicing engineers drawn from local industry. Each judge completes two evaluation rubrics which rate the technical merit of the project and the professionalism of the presentation. The compiled data provide one measure of student outcome attainment and an external perspective of the results. The EET final capstone presentation is delivered to the instructor with other audience members being fellow students and invited third-parties mostly from industry.

The final point of contrast involves supplemental resources including how project costs are handled. In MET, industry sponsors bear the full cost of raw materials and fixtures and serve as technical resources. In EET, students pay for all electronic components not available from the Department's inventory. Historically, the student's cost share has ranged from less than $100 to a maximum of $500. In hardship cases, the Department has been willing to absorb the project costs. In both Departments, faculty other than the instructors act as technical resources.

Benefits & Trade-offs

The course frameworks for both MET and EET capstones utilize established project management tools and techniques. A sequence of interim and final deliverables comprises the body of assessed student work. The due dates for these deliverables are distributed to equalize the documentation workload and avoid an 'end of the semester' crunch as shown in Table 1.

Deliverable		**Description**	**Due Date (15 Week Semester)**
Proposal	EET	Goal and key design features of the prototype	Week 1 (draft) Week 2 (final)
Statement of Work	MET	Description of the design or testing requirements and deliverables	
Weekly Progress Reports	EET	Highlight of progress, issues and plan for resolution	Weeks 2-14
	MET	Same as above plus timesheet, PowerPoint slides accompanied by presentation	
System Design	EET	• Functional block diagram • Detailed design including component specs, and electrical schematics • List of components with part numbers and drawing references • Description of test and performance criteria	Weeks 3-12
End-of-Semester Deliverables			
Formal Oral Presentation	MET	Team presentation to a panel of judges	Week 14
Peer Team Evaluations	MET	Self-assessment by team members	Week 14
Final Report	MET	Comprehensive report in hard copy, DVD of slides	Week 14
	EET	Comprehensive report in hard copy	

Table 1 Capstone deliverables

MET over time has cultivated industry sponsors for sourcing capstones. Typically, sponsors provide a unique Statement of Work (SoW) that outlines the objectives, tasks and results required with the goal being to complete a functioning design or to execute a testing protocol. In response, teams develop detailed project plans and manage the work to completion. On the other hand, EET projects are internally-sourced. Based on faculty and instructor input as well as independent research, the teams craft a design proposal to build and test a working prototype. Both project sourcing approaches have advantages and disadvantages that must be addressed and managed to be successful. As noted above, each program has evolved a preferred sourcing method. Table 2 provides a summary of these trade-offs.

Industry-sponsored	**Advantages**	Sponsors: • Supply projects and provide resources • Provide technical and management experience • Create a stronger sense of responsibility • Act as the voice of the customer • Participate in final assessment
	Disadvantages	Having sponsors may: • Require pre-planning before the capstone starts • Impact the planned project schedule • Change the SoW during the course of the project • Increase coordination workload of instructor • Increase the probability of failure
Internally-sourced	**Advantages**	Students teams: • Take ownership • Create and manage project schedules with minimal outside influence
	Disadvantages	• Projects may not have real-world application • Costs fall on teams and the Department

Table 2 Pros and cons of industry-sponsored vs. internally-sourced

As discussed earlier, capstones may be either design-oriented or test-based. The former is exclusively used by EET while both are encountered in MET. Table 3 identifies the pros and cons of each.

Design-oriented	**Advantages**	• Strengthens design skills
	Disadvantages	• Instructor must ensure appropriate rigor
Test-based	**Advantages**	• Industry sponsors source projects • Sponsor input and assistance throughout the project is available • Develops skills in testing and interpretation of data
	Disadvantages	• Prototyping design skills not fostered • Access to measurement equipment and expertise may be problematic

Table 3 Pros and cons of design-oriented vs. test-based

Some recent project abstracts for both MET and EET are provided below:

Evaluation of Corrosion Preventative Compounds (MET)

The objective of this project is to examine the galvanic corrosion of propeller hubs exposed to an electrolyte. 36 aluminum panels were drilled with seven holes. A bolt and washer were inserted into each hole, and fastened with stainless steel fasteners at 15 in-lb torque. The fasteners had been treated with 14 different anticorrosive compound coatings currently being used in industry. Each of the bracket panels have been either left bare, anodized or treated with chromate conversion to help simulate potential materials used to manufacture the hubs.
After the bolts, washers, and nuts were fixed to the panels, they were set into the salt chamber for spraying. At the conclusion of the salt spraying periods, the panels were removed, disassembled and examined to document the corrosive behavior exhibited on the compound joints of the aluminum panels. The visual inspection was quantified using a five point scale provided by the sponsor and the results were used to inform customers why particular compound coatings are more suitable than others for certain types of products.

Diaphragm Pressurization Device (MET)

A Diaphragm Pressurization device to measure the burst pressure of a Nomex reinforced rubber diaphragm was designed, constructed, and tested for Hamilton Sundstrand’s materials laboratory. The maximum design pressure of 1500 psi was provided from compressed nitrogen. The device was required to test burst pressure of new diaphragms and compare to those with known real or simulated service histories. Proper material for the device and bolts used to hold it together were constructed to size to avoid failure at any point during its testing. Numerous calculations for material thickness and bolt size were developed. Compression of the diaphragm while in the pressure vessel was also a concern. The design required that the diaphragm not slip out before it burst, which would render the data invalid. After construction of the pressure vessel, several ¾ inch pieces of the diaphragm were placed inside of it and pressure was applied. This presentation will describe details of the design, considerations for the fabrication, and preliminary test results

Low Power FM Transmitter (EET)

The objective of this project is to build, test, analyze and create a prototype of a low power FM transmitter. An FM transmitter is a portable device that plugs into a headphone jack or proprietary output port of a portable audio device such as a media player, guitar, CD player or an IPOD. The sound is then broadcast is mixed and sent out the transmitter at a frequency capable of being received by a commercial FM receiver. It will have a range of up to 30 feet (9 meters) and be compliant with FCC regulations. It will be powered using a normal 9V battery. The circuit will consist of three stages. First, a pre-amp with a variable voltage gain up to 10 will accept the incoming audio signal. An oscillator will generate the RF carrier in the commercial FM band. Lastly, a mixer will combine the baseband audio with the RF signal produced by the oscillator and feed it to a small antenna.

Audio Summing Playback Device (EET)

The purpose of this project is to design and build an audio summing and playback device. This device will allow the user to play along with a pre-recorded audio track for practice or entertainment purposes. There is currently nothing like this on the market with the exception of large mixing consoles. The device will contain an input jack that will allow an instrument to be plugged in, e.g. electric guitar. A second jack will be an input for an external audio source, e.g. IPOD or MP3 player. Separate volume controls will allow the user to combine the two signals in the desired proportion. The combined signal will be fed to an output capable of accepting a headphone connector so the user will be able to listen and play quietly. A switch to allow only the instrument input to be fed to the headphones will also be incorporated into the design. The device will be powered from a standard 115v, 60Hz wall plug with an internal power supply to generate the required DC voltages.

Interim documentation and presentation deliverables are an important part of all capstones. They provide a valuable opportunity for students to actively learn and apply project management tools and techniques. These deliverables must be prepared in parallel to the core work of the project; however, the work must be evenly distributed over the semester. Written weekly status reports are required for all capstones in which teams describe what has been done since the last report, identify issues that have surfaced, what is needed for resolution and a plan looking forward.

In addition to written weekly status reports, METs are tasked to deliver regular oral presentations. These practice sessions have been paying dividends for several years and were recently re-enforced by others[9]. Verbal and written feedback is provided on a team and individual basis from the instructor, industry sponsor and a writing consultant. Slides are improved and new ones created, students sharpen their speaking skills and team synergy is strengthened. The content evolves over the course of the semester into that of the final presentation. Table 4 shows the pros and cons of the interim evaluation methods.

Interim feedback & evaluation	**Advantages**	Oral • Improves team skills and clarifies roles and work to be done • Strengthens presentation skills • Enables final presentation slides to be refined and improved over several iterations Written • Evenly distributes the documentation load • Final report content is prepared ahead of time • Students manage multiple tasks simultaneously • Energy of the entire team is leveraged
	Disadvantages	Oral • Requires slide and presentation effort every week • May detract from design and testing activity Written • Burden of documentation adds to other project work • Students are not familiar with many document requirements

Table 4 Pros and cons of interim feedback and evaluation

All capstones use peer assessment administered at the end of the semester during the final presentation. MET capstones employ an external panel of judges, a natural extension of industry-sponsored projects. The quality of assessment and interaction between the panel and the teams during the final presentation is good since some judges have been indirectly involved in the projects. The peer and panel assessment data is both semantic (comments) and objective (numerical). The writing consultant provides input on the final grade to the instructor. EET capstones do not use a judging panel therefore assessment of student work rests solely with the instructor. Table 6 lists the pros and cons of assessment techniques.

Peer assessment	**Advantages**	• Provides a better view of individual performance
	Disadvantages	• Sometimes teams give high grades to all
Writing consultant	**Advantages**	• Strengthens organization of material and recursive editing of written and oral content • Provides a professional perspective to the final assessment process
	Disadvantages	• External funds are needed to sustain the resource
External judging panel	**Advantages**	• Provides an industry-based external perspective • Creates a more formal setting which energizes teams
	Disadvantages	• Requires coordination and scheduling • Easy to employ assessment tools are needed

Table 6 Pros and cons of assessment techniques

Regarding supplemental resources, MET industry sponsors supply technical assistance and subsidize the cost of projects. In addition, sponsors may provide access to laboratory facilities, fabrication shops, equipment, raw materials and components. MET supplements the capstone instructor with an industry representative, department faculty and a writing consultant. Students meet and work with the company representative to report accomplishments and plan next steps. The writing consultant evaluates interim document deliverables, provides critique during the semester, and participates in the assessment of the final report. Department faculty provide technical assistance on request. In EET, students pay all external costs; however, in-stock electronic components are made available. EET capstones are overseen principally by the instructor with department faculty available on request as technical resources. Table 7 shows the pros and cons of supplemental resources.

Supplemental resources	**Advantages**	Technical • Technical assistance improves overall project quality • Burden of capstone course is shared across faculty Monetary • Budget can be capped and managed • Funding is known before projects are formed
	Disadvantages	Technical • Program becomes dependent on external sources Monetary • Adds to program cost if absorbed by the institution

Table 7 Pros and cons of supplemental resources

Conclusions

MET and EET have taken different approaches in the planning, organizing and exectuion of their respective capstone projects. The primary areas of contrast are: 1) project sourcing, 2) type, 3) interim feedback and evaluation, 4) final assessment, and 5) supplemental resources. The approaches used in each area have advantages and disadvantages that necessitate trade-offs and careful management.

It is anticipated that capstones will continue to evolve with the most likely areas of improvement being: 1) better preparation embedded into the curriculum prior to the capstone, 2) increased use of external judging panels, 3) integration of additional project management techniques, 4) greater focus on societal and ethical responsibilities, 5) use of web-based collaboration tools to overcome time/distance, and 6) fostering competition between the teams. Interest has also surfaced to form interdisciplinary and cross-program teams; however, the issues of resourcing and coordination, assessing performance, suitable project rigor and semester timelines must be addressed.

References

[1]Milanovic, I. M., and Eppes, T. A., 2008, ‘Modular, Adaptable, and Reusable Approach to Thermal-Fluids Outwitting the Norms (MARATHON),’ 2008 ASEE Annual Conference, Pittsburgh, Paper ASEE-2008-440.

[2]Magleby, S., Todd, R. H., Pugh, D. L., and Sorensen, C., 2001, ‘Selecting Appropriate Industrial Projects for Capstone Design Programs,’ *Int. J. Eng. Ed.*, 17, 4 and 5, pp. 400-405.

[3]Jordan, A., Schell, D., 2002, ‘Design Projects and Industry Engagement in a Mechanical Engineering Technology Curriculum,’ 2002 ASEE Annual Conference, Montreal, QE.

[4]Otieno, A., and Mirman, C., ‘Engineering Technology Capstone Experience – An Industry Based Partnership,’ 2003, *Int. J. of Modern Eng.*, 3, 2.

[5]Myszka, D., 2003, ‘Capstone Projects that are Industry Sponsored, Interdisciplinary, and Include both Design and Build Tasks,’ 2003 ASEE Annual Conference, Nashville, TN, Paper ASEE-2003-123.

[6]Farrel, S., Hesketh, R., Slater, C., and Savelski, M., 2004, ‘Industry and Academia: A Synergistic Interaction that Enhances Undergraduate Education,’ 2004 ASEE Annual Conference, Salt Lake City, UT, Paper ASEE-2004-1517.

[7]Blust, R., and Myszka, D., 2005, ‘Merging Design Competition and Industry Sponsored Projects,’ 2005 ASEE Annual Conference, Portland, OR, Paper ASEE-2005-426.

[8]Fry, R., 2004, ‘The Benefits and Trade-offs of Web-Based Industry Sponsored Projects,’ 2004 ASEE Annual Conference, Salt Lake City, UT, Paper ASEE-2004-941.

[9]Emanuel, J., and Kerns, H. D., ‘Industry Based Capstone Design Projects: You Can’t Sell the Solution If You Can’t Communicate,’ 2007 ASEE Annual Conference, Hawaii, Paper ASEE-2007-2246.