Integration of Industry-Sponsored and Design Competition Projects in the Capstone Course

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Abstract – For the past ten years, the capstone senior design projects in the Department of Mechanical Engineering at the FAMU-FSU College of Engineering have evolved from a few (~10%) industry-sponsored projects to an overwhelming majority (~90%). This transition was adopted based on the fact that these types of projects offer realistic problems (open-ended), foster a more industrial-like environment, and assist in the placement of students. Unlike industry-sponsored projects, competition-based design projects, favored by many engineering programs, present problems that are fairly well-defined, with concise guidelines, constraints, and specifications as stipulated by the professional societies that usually sponsor these student competitions. The two approaches are therefore complementary of each other. This article compares the effectiveness of these types of projects: the completely open-ended externally sponsored and the relatively well-defined competition-based design projects, with the aim of identifying "best practices" for integrating the two forms of projects in the capstone design courses.

Keywords: Industry-sponsored, Design competition, Capstone Course, Best practices

INTRODUCTION

Undoubtedly, senior "capstone" design projects have been recognized to represent an excellent vehicle that not only round out a good engineering education, but also provide the appropriate platform for students to apply design thinking and transition into a professional career [1]. Many universities have adopted this model for their engineering curricula [2, 3, 4], and is currently mandated by the Accreditation Board for Engineering and Technology (ABET).

At our department, this course was first introduced as a one-year sequence within an integrated curriculum in the 1999 academic year [5]. Since then the senior design course has undergone a gradual evolution from year to year as a result of our ABET internal review process which incorporates the lesson-learned from previous teaching cycles. At its inception, the course was conceived as an integrated lecture plus project where the lectures and projects were administered concurrently. As projects made progress, the lectures would attempt to follow the design cycle as best as possible. This approach, however, showed major weaknesses one of these being inevitable mismatch between lectures and projects [5]. After delivering the course as an integrated unit of lectures plus project for three years, a major paradigm shift was implemented in the program. It was decided to split the lectures into a separate (semester) course, with traditional delivery and grading, and leave the capstone design experience as a project-only course. These revolutionary changes have fostered a steady growth in industrial participation as shown in Figure 1. When the course was started in 1999 we had only 2 projects (12%) sponsored by an outside industrial partner. As the course matured, the department has been able to attract more and more industrial sponsors; today almost (~90%) all the senior projects are sponsored by industry. These design projects meet real industry needs and provide the students with interaction with practicing engineers. A complete list, project descriptions, and photos of some of these projects are available on our Web site at http://www.eng.fsu.edu/ME_senior_design/.

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Although the majority of these projects are industry-sponsored, a few of them are either sponsored by internal faculty or involve national design competitions. Most of our competition-based capstone projects are sponsored by the American Society of Mechanical Engineers (ASME), American Institute of Aeronautics and Astronautics (AIAA), or the Society of Automotive Engineers (SAE). While the industry-sponsored projects are open-ended and harbor student-client (industry) relationship and the ability to pursue design under conditions of shifting requirements, competition-based projects are fairly well-defined, with concise guidelines, constraints, and specifications as stipulated by the professional societies. Despite these diverse differences, our experience show that their 'strengths' and 'weaknesses' are worthy of 'mixing'.

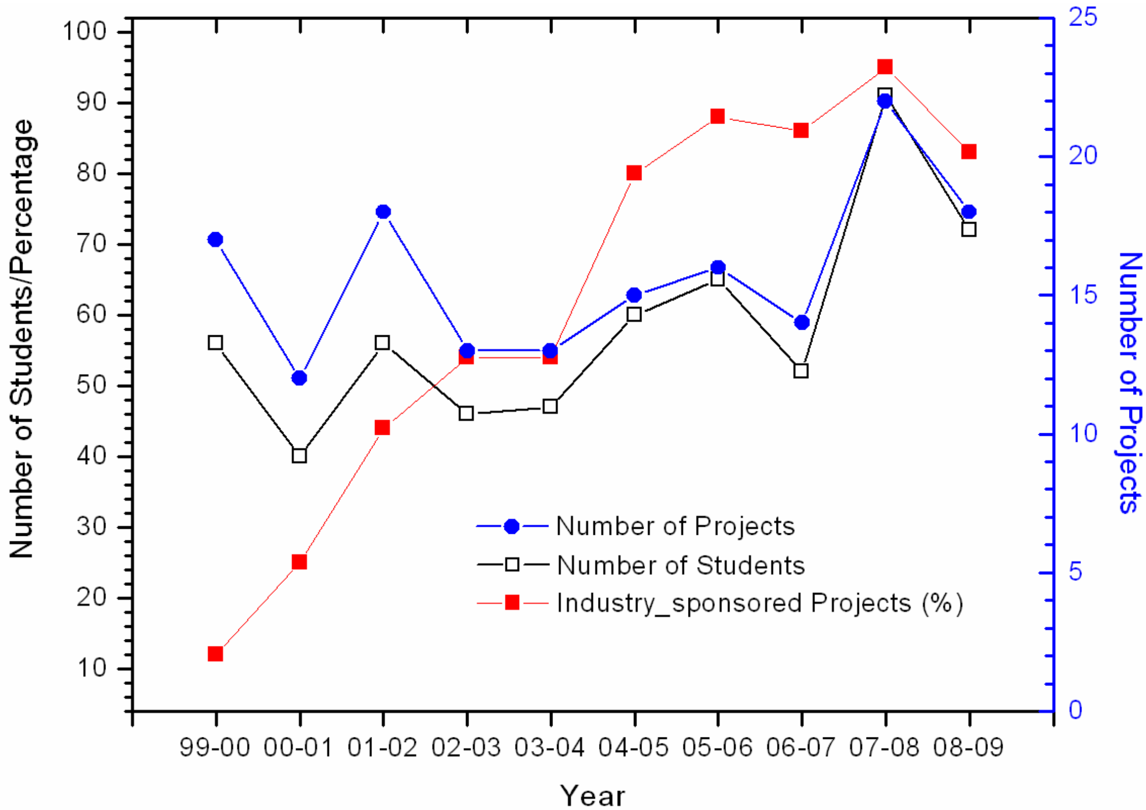

Figure 1: Growth of industry sponsored projects for the past 10 years

INDUSTRY-SPONSORED PROJECTS

Industry supported projects have been shown to provide great benefits in an academic design program since they often expose students to real-world challenges [6]. These projects offer realistic problems (open-ended), foster a more industrial-like environment, and assist in the placement of students. However, industry sponsored projects are not uniform, vary widely in scope, and care should be taken because they can also become problematic to manage. For industry-sponsored projects to serve an appropriate educational role in the program, and at the same time provide value to industry, they have to be carefully selected, monitored, and managed. Leaning too far to either the academic or the industrial side can prove to be problematic. Thus, it is critical for the capstone instructor to closely monitor the relationship between student teams and industrial sponsors.

In order to provide projects that closely simulate the industrial environment, the Department of Mechanical Engineering at FAMU-FSU College of Engineering works with the Mechanical Engineering Advisory Council (MEAC) and other industry contacts to identify partners who can sponsor high-quality and engineering-relevant projects. Moreover, the department has integrated effectively the capstone experience in its continuous assessment process by involving industrial project sponsors and MEAC members in the annual project review as external evaluators.

The task of securing enough projects and corresponding funding to feed the program, although always daunting, has become somewhat easier in recent years due to two important factors:

- Active involvement of MEAC, which has been very proactive at helping the department to secure participation from divisions and engineers from their home organizations, and
- A significant fraction of “repeat business” with many companies returning in subsequent years to sponsor more projects (see Table 1) after realizing the benefits of their involvement (new design ideas, building and testing of early prototypes, exposure to faculty and students, recruiting opportunities, etc.)

At this point we have a solid base of industrial partners to secure enough industrial projects, although every year we have some sponsors that cannot return, or are not in a position to sponsor. Coupled with steady enrollment growth, this makes project harvesting always challenging, so the department is continuously searching for new opportunities to partner with industry.

At the end of the school year the capstone course concludes with a one-day review event featuring final presentation and open house. All teams make presentations describing their projects and the results obtained in front of students, faculty and external sponsors. Following the presentation, students showcase their projects with posters and the actual hardware built by the teams. During the review session, external sponsors and MEAC members are invited to serve as panel judges and give feedback not only to the student teams about their projects, but also to the department on any strengths and weaknesses of the curriculum as observed by them from the capstone design review. The capstone open house is followed by a two-day MEAC semi-annual meeting where the feedback from industry is further discussed and plans are drawn to integrate into the capstone course and the curriculum in general. This tightly interwoven relationship between the capstone course, curriculum evaluation, and MEAC participation has served the department well in many fronts: continuous improvement of the capstone course and curriculum, harvesting of relevant projects for the capstone course through strong industrial involvement, and expanded career opportunities for our graduates.

Table 1: Industries sponsoring projects for the past 10 years

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cummins	Cummins				Cummins	Cummins	Cummins	Cummins	Cummins
NHMFL		NHMFL			NHMFL			NHMFL	NHMFL
ASHRAE	CAPS		CAPS			CAPS			
SubZero	Aquatek	Lockheed	Lockheed	Lockheed	Lockheed	Lockheed	Lockheed	Lockheed	Lockheed
		Shaw Ind	CERN			CERN	CERN		
			Sandia		Sandia	Sandia		Sandia	
			Eglin	Eglin	Eglin	Eglin	Eglin	Eglin	Eglin
				Boeing	Boeing	Boeing		Boeing	Boeing
				Benedict Eng		Talla-Tech	Talla-Tech	FDH	FDH
								Danfoss-Turbocor	Danfoss-Turbocor
									NASA
									Harris
									Tyndall-AFB

NHMFL – National High Magnetic Field Laboratory, CAPS – Center for Advanced Power System, FDH – Florida Department of Health, ASHRAE - The American Society of Heating, Refrigerating and Air-Conditioning Engineers, CERN - The European Organization for Nuclear Research

Although industry-sponsored projects are beneficial, there are however, consequences that need to be addressed. Besides the commitment by the sponsoring agent, these projects require willingness of the liaison person (engineer at sponsoring company) to dedicate some time, as well as to have a vested interest in the success of the projects. The selection of this person deserves special attention. As important as defining good projects for the students to work on is the industrial liaison that will work with the students and serve as “customer”. In a large class with only one faculty acting as instructor/coordinator, the quality of mentorship offered by our industrial partners is of critical importance for the success of the project. Having strong backing from management is not enough if the individual mentor does not “buy into” the concept of capstone project sponsorship. He/she needs to perceive the value of industrial involvement and the benefits of the student work, however minor they might be in the context of the organization’s goals. These benefits could be direct, in the form of project results, data, or prototypes; but they could also be indirect, such as potential recruitment targets, image creation within the entire graduating class, or development of industry-academic contacts.

Another aspect which deserves special attention in a capstone course is intellectual property (IP) issues and non-disclosure agreements (NDA). We clearly prefer projects that do not expose corporate privileged data or otherwise classified materials. It is important for companies to understand that these projects are, above all, an educational vehicle. By the most part our industrial sponsors understand this and provide projects that appropriately mask or box the problem so students can do relevant work without exposing confidential or proprietary data. This is very important given the need for teams to present their work, not only in class, but to prospective employers as well. We have been unsuccessful to come up with a good model since the university refuses to execute any type of NDA document, or to agree to release any IP resulting from these projects. This has been an impediment in some cases to either obtain a project or to execute what could have been high-quality projects from an educational standpoint. It is an area where we will continue to work in order to obtain some release from the university so that we can engage a wider range of corporations and projects.

DESIGN COMPETITIONS

In design competitions, a team of students is assigned a project in which at least one other team also solves the same problem under the same constraints, and the products produced by the teams are objectively evaluated in a way that causes them to be ranked relative to one another. Competition-based design projects are excellent for the hands-on educational experience of the students since they provide practical objectives to meet and the physical product (hardware) to work on. They also require teamwork and the pressure of having a working prototype to meet competition deadlines and to outperform other teams. The competition atmosphere often provides students with an added incentive and motivation [7, 8]. This enthusiasm is largely due to a sense of competition between teams.

Apparently, a team motivated by competition performs better and learns more than a team merely working toward “completion” of a project. The fear that the alternate team may outperform them is sufficient motivation. This is similar to real world situations when multiple companies may be competing for a contract and must provide a better product than their counterparts, or need to compete on cost and/or quality in a global marketplace..

A competitive design project offers actual learning benefits not realized with non-competitive design project. In the former, the pressure of outperforming others encourages the students to focus on simple, inexpensive, and robust designs that work.. In the real world, a poorly designed product will not stay on the market very long. On the contrary, in a non-competitive design project, a team does not have to be “better” than another team. The product produced is "one of a kind" and its performance is only evaluated (validated) in the absolute term against the design criteria. The lack of competitiveness usually mars cost-effectiveness or creativity in these set of projects.

There are two variants of ‘competition-based’ design projects: competition between teams from different schools (regional or national design competitions) and competition among teams in the same school. For the past 10 years, all our senior design competition projects at the Department of Mechanical Engineering, FAMU-FSU College of Engineering, have been collegiate design competitions, sponsored by engineering societies such as the ASME, AIAA, and SAE. These projects were competitive between teams from different schools, but represented a non-competitive design in the context of the design class the students were taking.

National design competition projects are designed not only to allow students to learn elements of design, organization, and planning, but also teamwork, manufacturing, and competition. Once again, the students are inspired by the air of competition among teams, and work hard for the opportunity to represent their school in the national contest. However, because there is a competition involved, there are also very clear "rules." These rules can be translated fairly easily into performance requirements for the design. Consequently, the open-ended element may not be sufficient, making initial stages in a competition-oriented design much more straightforward than dealing with a "real world" open-ended design problem. The majority of these projects are therefore fairly comprehensive, well-defined, streamlined, with concise guidelines, constraints, and specifications as stipulated by the professional societies. To alleviate this problem, we have ensured suitable selection of design competitions that are more open-ended. For example, SAE has held a yearly formula car competition among universities from all over the world for over two decades. This event provides students with the once in a lifetime opportunity to conceive, design, fabricate, and race a formula style racecar. The specifications on frame and engines are minimal so that the knowledge, creativity, and imagination of the students are challenged. Performance is the key to success. ASME holds multiple design competitions each year. This year ASME is teaming up with Boeing to sponsor the competition where the objective is to design and build a remote controlled robot. Inspired by the success of the Phoenix Mars Lander's mission, NASA would like to include on its next mission a radio-controlled vehicle to retrieve small rock samples. This device could be controlled from the spacecraft if the mission is manned or from Earth on an unmanned mission. Thus, the remote-controlled robot should operate in a specific obstacle course, be able to climb over wooden barriers, collect plaster rocks, transport the rocks to a receiving area, and drop them off in a designated deposit area. Again, the specifications are minimal allowing the performance be based on the time, weight, power, location of rocks collected, ability to stay within boundaries, and accuracy in dropping off rocks in the receiving area.

Students taking national design competition projects, on the other hand, lack student-client (industry) relationship, and the products designed for competitions generally have no practical use outside of the competition, which does not give students the feeling that they have contributed to an organization or society by providing a solution to a relevant problem. Competing design teams often get the opportunity to see the tangible results of "paths not taken." Design is an iterative process of creating alternatives, modeling and analyzing the alternatives, and then choosing the "best" alternative. When a team sees the construction and performance of the artifacts produced by other teams, they may see the result of pursuing a path which they had considered and rejected. This causes them to reflect about whether or not they did make the best choices, and whether or not their modeling and analysis were appropriate.

CONCLUSIONS

The capstone senior design course in the Department of Mechanical Engineering at the FAMU-FSU College of Engineering has proven to be an excellent vehicle to educate our students in team-based design, and the application of engineering fundamentals to real-world problems. The program has evolved over the last eight years and reached a high level of maturity. This capstone course has allowed us to create a good foundation for attracting industrial partners that provide project ideas, funding, and mentorship to turn the experience into a much more realistic platform for educational delivery.

Following this success, it is logical for us to explore the possibility of integrating industry-sponsored and design competition projects in the capstone design course. Design competitions offer a superb way of creating enthusiasm and foster strong teamwork. In addition to national design competition projects, we intend to introduce a sense of competition between teams taking industry-sponsored design projects, which shall promote motivation and an atmosphere of realism.

From our experience, we can draw some conclusions in terms of pros and cons for each kind of project (industry-sponsored or national competitions). Industrial projects provide a superior platform to teach systems engineering and the product design cycle methodology as most problems are truly open-ended and often exhibit shifting requirements. Students gain significantly from the interaction with a practicing engineer sponsoring the project. In the end, students feel a higher sense of achievement and feel better prepared for a professional career. On the other hand, national competitions improve teamwork and provide an excellent platform for design and prototype test. The projects tend to be hands-on and provide a better avenue for prototype development, test, and iteration, sometimes in detriment of a more rigorous analysis and design methodology. One of our challenges moving forward is to blend the best each kind of project has to offer as educational platforms.

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