AC 2012-3799: FROM THE INDUSTRY TO THE STUDENT: PROJECT MANAGEMENT OF AN INDUSTRY-SPONSORED MULTIDISCIPLINARY CAPSTONE PROJECT

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From the Industry to the Student: Project Management of an Industry-Sponsored Multidisciplinary Capstone Project

Abstract

The Engineering Education Innovation Center at The Ohio State University has offered, through its Multidisciplinary Engineering Capstone Design Program a broad range of opportunities for engineering and non-engineering students by incorporating authentic industry-sponsored projects into the curriculum. The program provides students the opportunity to apply their education and develop professional skills in real-world problems by incorporating different student and industry interests through its four sub-programs; Industry-Sponsored Projects, Industry-Sponsored Product Design Projects; Social Innovation and Commercialization; and Joint Mechanical/Bio-medical Projects.

The program enriches the learning experiences of the students by providing an opportunity for student design teams to contribute to real industry products by experiencing the complete design cycle including define problem, create requirements/specifications, create design concepts, create detail design solution, build prototype, validate design, refine design and implement design. Professional skills are developed by improving the students' awareness of engineering practices through developing skills that include communication, engineering ethics, professional presentation and etiquette, and project management. Industry sponsors provide domain specific knowledge through all aspects of the design process.

This paper provides an overview of project management requirements, techniques, and teaching strategies to enrich the learning experiences through the aforementioned course sequence methodologies for an automotive industry-sponsored capstone design project. The points-of-view of an industry sponsor, academic program coordinator, project faculty advisor, and the engineering student will be examined.

Introduction

The Engineering Education Innovation Center has focused on providing senior students an opportunity to apply their education and professional skills to real-world engineering problems. The center has developed a capstone program for graduating seniors as an elective for their last three quarters at The Ohio State University. Over the past few years, EEIC has encompassed many different colleges from business, to engineering, to humanities, and industrial design into their capstone program.

The Multidisciplinary Engineering Capstone Program challenges students to apply their academic and professional experiences to a real-world project. The project comes from an industry sponsor that is not only supported by academic faculty and staff but also by the company's financial and personnel support. The sponsor finds benefits in supporting these projects through direct contact with students as potential employees and promoting their company on campus. As a secondary benefit, the company obtains a value-added outcome from the project from both the engineering design process and results of the project that the students follow. Since fall of 2009, the program averages 15-20 projects involving 70-80 students per academic year and has had projects from over 15 companies.

When approaching companies, the objectives of the Multidisciplinary Engineering Capstone Program must be clearly stated to ensure the program's success. As stated above, the main objective of the program is to give students the opportunity to apply their education and develop professional skills to a real world project. The focus of the program is to develop a student's skills to be a successful professional in the engineering field. Expectations for students, faculty advisors and company sponsors are communicated to all participants.

Since each of the engineering departments offers their own respective Capstone course, the Multidisciplinary Engineering Capstone is an option for students to take in place of their respective discipline Capstone or as technical elective credit. Since this is an option for students, the program can be selective on which students would best fit into these types of industry sponsored projects. In order to help increase the success of students and the projects, students are screened before registering for the course. Students submit a professional resume and are interviewed to discuss the program and expectations. During the meeting, the program coordinator evaluates the student's initiative, time management, leadership, teamwork, and communication skills.

After the students have been interviewed, they are placed in one of the four sub-programs that EEIC offers. These sub-programs include; Industry-Sponsored Projects, Industry-Sponsored Product Design Projects, Social Innovation and Commercialization (SIAC), and Joint Mechanical/Bio-Medical Projects. The SIAC program has been a collaboration effort between five different colleges at The Ohio State University; College of Arts, Humanities, Engineering, Business, and Medicine. The SIAC program has been designed with a goal to have students understand the importance of product design that is self-sustaining through commercialization. The students work with local companies to reduce costs and help a product in development. There is the Joint Mechanical/Bio-Medical Project which has been a collaboration effort between the Colleges of Allied Medicine and Engineering. Within this sub-program, students design, build, and test a prototype that has a focus in biomechanical design.

Currently, most engineering students are placed in the Industry-Sponsored Projects. There are two different versions the Industry-Sponsored Project; industry project and a product design. Product design focuses on students designing a new or improved product for a company to sell or market. Students partner with industry and have the goal of reducing the costs and develop a product. Industry projects encompass an engineering-based problem in industry that encourages students to design a. Multidisciplinary engineering student teams will design, build, and test the product prototypes that will provide a potential solution to the problem statement.

The Industry-Sponsored Project Program offers students an opportunity to understand project management, professional communication and presentation, and engineering ethics through the required deliverables from the project coordinator and faculty advisor. Students will see a project's design cycle from starting with a problem definition, to creating requirements and specifications for the project, design concepts, creating a detailed design solution, to building a prototype and validating the design.

Industry-sponsored projects require participation by multiple parties to ensure success. A commitment by the company to maximize project value to the company and to help ensure an effective learning experience for the students is fundamental. The EEIC's program coordinator and academic advisors carefully select companies to assure the necessary collaboration and commitment. Faculty advisors are selected for each team and, in most cases, have experience working with student teams and industry projects; and who have some degree of technical familiarity with the project scope. Throughout the project, the team experienced that communication was essential in managing the project; and was a key factor for the success of an industry-sponsored and active participants within the capstone design-build projects.

An Industry-Sponsored Project Program

EEIC offers engineering students from multiple disciplines to work together on capstone design-build-test projects and have a direct experience with real-world engineers through the industry-sponsored program. The capstone design course sequence has been developed to meet accreditation board for engineering and technology (ABET) requirements while, providing a service to industries and facilitating innovation through education.

One important objective for the capstone design project to provide a team-based experience that includes all aspects of engineering design and development. This includes student exposure to all activities within the design process from initial concepts through prototype development and testing to a final product. This objective also includes successfully providing students with awareness of and experience with the iterative nature of design throughout the design cycle.

The students begin with an introduction course with a focus on engineering design principles, design processes, professional development skills, and project management. At the end of the introductory course, multidiscipline engineering student teams are formed, based on individual interests with the industry-sponsor project available, and enter into the project specific design-build-test course sequence.

The objectives, laid out by EEIC and ABET, for the design industry-sponsored project specific course sequence, utilizing lessons learned in the introductory course include:

- Students are to demonstrate professionalism by exhibiting integrity, providing leadership in a project to ensure the project success
- Students are to produce quality designs that represent not only of themselves but of the industry company and the college. The designs must satisfy the performance requirements and constraints
- Students are to establish team relationships with other members on the team, the advisor, the program coordinator, and the industry sponsor.
- Students are to manage the project schedule and the resources by monitoring their own expenditures, their work assignments, and their course plan.
- Students are to apply their prior knowledge, research, and any ideas in addressing the problem when trying to generate a solution.

- Students are to test and defend their design by having validity in their design prior to testing and the route they choose.
- Students are to communicate by use of formal and informal communication means with other team members, advisors, and the industry to ensure project success.

This paper will set forth the successful project objectives, the curriculum development and the views from the industry, the pedagogical approaches, and the views from the students in meeting these objectives.

During the introductory course and organization between the university through the program coordinator and the industry sponsors, the coordinator recruits academic advisors, typically faculty within the various engineering departments, to further instruct and advise the students with each of the design-build projects. Before the student-teams begin their project specific design process, the program coordinator and industry-sponsor liaisons develop a project summary sheet including the project background, and industry-sponsors student-directed design goals, objectives, and design and prototype expectations are listed. The descriptions of the required engineering disciplines are also listed. The faculty advisor, for that specific project, meets with the program coordinator and reviews the summary sheet; and if deemed necessary, meets with the industry-sponsor liaisons to revise and update the summary sheet to ensure that the academic requirements and the important academic experiences of a senior-level capstone project is established and maintained.

Faculty Advisor Role

During the first term of the course sequence the academic faculty advisors are provided with the faculty/student guide and introduced to the selected project(s). The faculty advisor familiarizes themselves with multidisciplinary course sequences and the common primary tasks. The tasks include:

- Guide the team to follow the design process with a strong focus on "defining the problem" and meeting established benchmarks for process and time,
- Foster the implications of engineering decisions based on business and technical factors,
- Emphasize and promote activities based on accomplishment of the primary learning objectives,
- Coach the team in a manner that creates a collaborative atmosphere,
- Take overall responsibility for the oversight of interface with the customer,
- Stimulate team members to be self initiating and assist students to find the necessary technical resources to understand and solve the design problem, and
- Work in concert with the EEIC multi-disciplinary program coordinators.

The faculty advisor is expected to invest approximately 15% of their time per week meeting and advising the students during the design and testing processes. The guide also provides the faculty with overall guidelines and expectations common for each design project that include: attend the kick-off meeting with the student team and sponsor organization; advise the student teams; hold the student team accountable for their responsibilities; grade the team's overall performance and value individual contribution; lead efforts to improve team effectiveness;

encourage students to seek personal development as a result of formative assessments; promote consistent communications guidelines; and participate in summative assessments based upon standard rubrics; with project specific details left to the faculty advisor and student-team. Each faculty is expected to develop with the project's individual and student-team guidelines and expectations.

Throughout the quarters, students are to provide related assignments and deliverables. These deliverables are to establish and maintain meeting regularly scheduled tasks, common for all project, throughout the design process. A key factor in making a project successful is establishing professional communications with teammates, faculty advisor, and the industry, which includes well written and organized documentation. These assignments are in the form of written assignments and oral presentations. Each student-team is required to maintain a project notebook throughout the design project and includes; all assignments, oral presentation documentation, meeting notes, and mid-term progress and final written reports. The following section discusses further detailed development for a case-study design project.

An Industry Sponsored Project in Review

It should be noted that this project, in specific, began with a prior and established student-team/faculty relationship in which led to efficiency within the effectiveness of communication skills and increasing expectations of the faculty advisor for the team. The faculty advisor carefully increased the project scope, while maintaining the industry-sponsored set design objective, to emphasize the main objective and the importance of team interaction and collaboration when working on "real-world" design problems.

Project Introduction

Fuel economy has been a major focus within the automotive manufacturers in today's world. Fuel economy has not been only regulated by government standards in many countries, but it has been an important aspect to potential customer's when choosing a new vehicle. With choosing a Sport Utility Vehicle (SUV), customers are choosing to pick features like off-road traveling, hold up to eight adults, and store more cargo than a typical sedan or coupe, and disregard the feature of fuel economy. SUV's have been known for having a low gas usage per distance travelled. One solution to increasing the fuel efficiency of the SUV is to redesign the exterior design. Having an aerodynamic body decreases the drag on the vehicle which will consequently reduce the fuel usage per mile. The goal that the automotive industry sponsor has proposed has been to reduce the exterior shell of a typical 2011 SUV and design it for the year 2020 by having the objective of reducing the drag by 30 percent. By presenting a 2020 design timeframe, gives the opportunity of a major model change. This gives the students an open-ended project compared to a 2015 timeframe, which restricts students to just a minor design change to focus, for example, a wheel well or a side skirt.

When choosing a capstone theme, the automotive industry sponsor benefited from fresh ideas and solutions that may not have previously been considered. It was thought that using engineering students, without prior knowledge of industry constraints, could potentially unlock new ideas that could improve future product and benefit the customer. Upper body aerodynamic drag is one of the largest contributors to overall vehicle drag, which directly impacts fuel economy. Therefore, having a student-team that included aerospace engineering students would benefit a project with the focus on improving vehicle aerodynamics.

The students were shown a previous project that was researched within the company that was similar to the proposed capstone project. With only a few dimensional constraints, the students were asked to develop their own vehicle that focused on aerodynamic drag reduction. The student-team was encouraged and utilized all available tools throughout the university during the design process.

Project Setup

The project student team and faculty advisor met at the beginning of the project to discuss early expectations, to organize the team, elect a team-lead, begin identifying individual primary and secondary roles; and as a team to clearly define the project problem statement based from the project summary worksheet developed and collaboratively revised by the industry-sponsor, program coordinator, and faculty advisor.

The student team was broken into groups from the start into areas of expertise and interests. These groups included the team leader, team manager, design technical lead, finance manager, CAD modeler, and systems engineer. The team leader was the liaison between the company and the academic team. The team manager was in charge of the technical papers, scheduling events, and managing the team, the design technical lead went in hand with the system engineers who were in charge of the overall design, the human factors, and feasibility of the vehicle.

While the student-team were delegating tasks and developing a clear problem definition statement, the faculty advisor was creating further detailed objectives and goals, as well as specific in-term deliverables for the project, to have the students take into account and update and revise their roles and responsibilities and project problem statement, at their next scheduled meeting. This was done specifically by the advisor to introduce and emphasize the iterative process of design, the aforementioned important objective; and encourage student-team interaction, starting with the problem statement. This also demonstrated early that the roles and responsibilities of the individuals may, and in some instances, be expected to change throughout the design process in order to ensure a successful outcome.

The student team had a governing goal of achieving thirty-percent drag reduction to a 2011 SUV for use in future SUV designs. The student team, faculty advisor, and project coordinator, through their excitement of the project, expanded the goals for the project. Some of these goals include; have more professional presentations to both academic and the industry and expanding the roles and responsibilities of each team member in providing a more in-depth design beyond external aerodynamics. The team utilized interests of the individuals and the expansion of the goals included considering within their designs. These included; vehicle dynamics and human factors such as aesthetic appeal, interior layout and comfort, and driver's visual capability.

Using the provided project objectives and goals, the student-team realized that a clear problem definition was a key factor in the design process. Having a detailed, researched definition helped make the project successful in meeting program and project objectives.

Project Management and Overview

Some project material deliverables were standard to the Industry-Sponsor Project Program set by the program coordinator. All teams were to maintain an intellectual property project notebook which housed the team meeting notes, design picture concepts, and, in the case of the specific project discussed, the computational fluid dynamics (CFD) and experimental results. All teams were to create a team charter which had the team expectations and distribute team into roles with the responsibilities. In the charter, each team member was assigned a primary relationship like team leader, technical leads and managers and secondary roles with the responsibilities associated with each role.

After a clear problem definition and team member's roles and responsibilities were established, the team developed a Gantt Chart (team schedule) for the entire project. Below is the Gantt Chart for the automotive industry sponsored project.

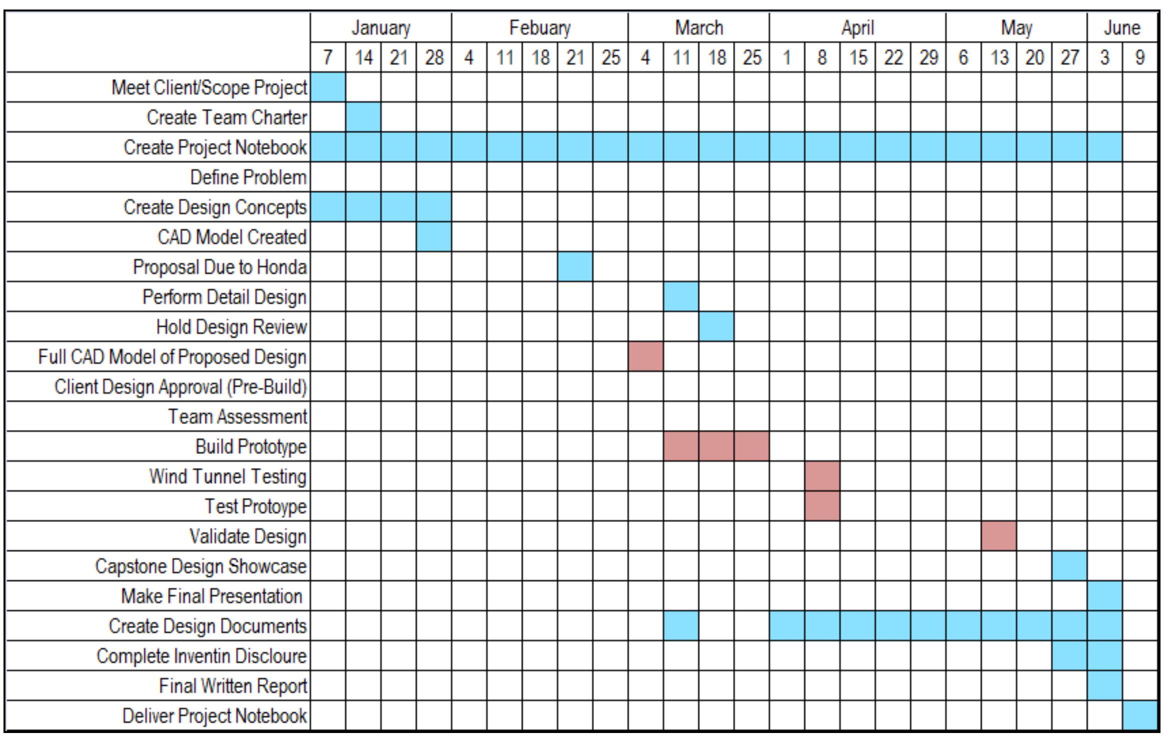

Figure 1 – Gantt Chart for a Successful Capstone Project

The automotive industry sponsor provided wind tunnel research capability and available dates for testing. The available dates provided a deadline for the specific project hurdles and the project Gantt Chart was built around those dates. Once the Gantt Chart was established and approved by the facilty advisor and project coordinator, the students started researching main sources of drag on a typical SUVs. Discovering the primary sources of drag, the students started creating prototypes in a CAD software program and testing the prototypes in a CFD solver. The students went through multiple CFD investigations to discover any trends before finalizing a prototype. Throughout the process, the team met with the faculty adviser to discuss their findings and discuss further testing plans. Once completed, the team presented their findings to the project coordinator, faculty advisor and a panel of engineers from automotive industry sponsor.

The student team worked with the industry sponosor to develope a prototype, using the designed CAD model, that was used to for experimental wind tunnel testing. The model had a layer of clay on the surface, so the students could then make modifications to their model while in the wind tunnel. From the CFD and experimental results through the detailed designing phase, the students were able to achieve a drag reduction of 38 percent of that of a typical 2011 SUV.

The industry sponsored project required the participation by multiple parties throughout the design process to ensure success. The student-team learned that one of the main contributing factors to managing a project efficiently and effectively was the developed professional communications; and in the instance of this project, the communications between the students and faculty advisor and the students and the industry sponsor engineers. This was emphasized throughout the design process with the team presenting regularly scheduled project updates while meeting the deadline for using the wind tunnel facility. Professional and effective communication in managing the project was essential.

Observations and Lessons Learned

The program coordinator and faculty advisors placed emphasis on establishing good project management techniques and were covered often and early throughout the capstone course sequence. At the end of the program, students are required to emphasize the importance of project management and teamwork strategies they developed throughout the project.
The faculty advisor's involvement with the students and company contributes to the success by mentoring the team and making sure the project is progressing. The Program Coordinator relies on the faculty advisor to bring any issues to his attention to be resolved quickly to not hinder the project.

The major challenge the team dealt with was the constraint on time. A company offered to donate their time to produce the team's prototype to use for experimental testing but the team needed to provide the company with a CAD model. This was unanticipated when the team constructed the Gantt Chart. In order to meet the deadline for external support in model construction, the team revisited individual assignments and redistributed tasks accordingly to meet the unexpected shift in project time-frame. The team witnessed firsthand how new constraints that develop during the design process can alter and change the strategy and assignments.

Project Specific

From a Program Coordinator's point of view, the SUV Capstone project was a very challenging project. The scope and company's expectations needed to be managed to ensure they were realistic for a team of undergraduate students' to be successful. In addition, prototyping the design was an initial concern considering the students' experiences and potential resources both physical and financial that were available.

Due to the scope of the SUV project, it was very important for the coordinator to have an open line of communication to the team as well as the faculty advisor. "During the project, students worked very hard as a team and were very successful at not only designing and testing a physical prototype but also exceeding the project goals and expectations. The team exceeded the coordinator's expectations."

In considering future projects like this one, the coordinator needs to have a team of students that not only have the engineering discipline background but also have the initiative to meet the many challenges that will inevitably occur.

The automotive industry sponsor felt it was a large success, both for the students and for the company. "The students were able to practice their studies in a real world application. When the students are challenged to explore new 'outside of the box' ideas they help us keep a fresh perspective and an open mind. It's great for the industry and great for the students as well. They used CFD software to design and countermeasure their virtual model. They were then able to collaborate with our company to turn the virtual model into a working wind tunnel test model. They then learned the process to physically countermeasure that model to further reduce aero drag inside of a wind tunnel. At that point we were able to discuss feasibility issues and constraints that currently influence automobile design and aero countermeasures. We felt it was a great real world learning experience for these university students and demonstrated two different paths they could choose for a future career. Their overall design and individual ideas were unique and the results were above the expectation of our company. They worked as a team in design, construction and problem solving."

The student team felt that this project was a great experience not only as a capstone design-build project but in gaining an appreciation in the 'industry standard' that is used today, specifically within the automotive industry. The students learned the importance managing a project that included the importance of maintaining a design-process schedule and well established professional communications within the student-team and with the faculty advisor, program coordinator, and industry sponsor engineers.

Current and Future Work

With the increasing enrollment rates, EEIC is continuously learning and adapting to provide a successful undergraduate engineering multidisciplinary capstone experience. One resource that is currently being used for the cornerstone projects offered in the EEIC Capstone Program, is a student team-based survey, conducted at regular intervals throughout the design process for each design project.

The surveying was anonymous and asked the student teams to record time spent on design process activities. The design process for the design projects was broken into seven activities including project management which includes time management, task scheduling, team communications, and meetings. The additional activities were selected based on the common activities. The activities on the survey include: identifying solution options, indentifying constraints, performing research, performing analysis, evaluating analysis, and implementing design decisions. The average percentage of total time spent for each activity throughout the design project and the number of times each student team revisited the activity on a weekly basis was recorded. This information was requested to provide insight into the students' experiences within the design cycle.

The items discussed in this section reflect the beginning of a more thorough consideration of the student-teams academic experiences in multidisciplinary industry-sponsored capstone project-based learning environments. Given that the seven design and project management activities in the aforementioned team-based surveys represent a reasonably full set of activities for most any design project, several favorable outcomes are expected from analyzing the data, including how the project course "tempo" effects the design process and what events can occur to alter, in a positive manner, the overall design experience.

Conclusion

The EEIC Capstone Program challenges students to apply their academic and professional experiences to a real-world project. The Industry-Sponsored Project Sub-Program offers students an opportunity to understand project management, professional communication and presentation, and engineering ethics through the project's design process.

Industry-sponsored projects require participation by multiple parties to ensure success; commitment by the company to maximize project value to the company and to help ensure an effective learning experience for the students is fundamental; the program coordinator and academic advisors, with some degree of technical familiarity, to carefully select companies to assure the necessary collaboration and commitment; and engineering students and student teams excited to work in collaboration with the industry sponsors to solve "real-world" problems.

Through one successful student industry sponsored team, the importance of this type of learning has been documented. Through deliverables, the students were able to design, build, and test their designs in support of an automotive industry sponsor. The project not only benefited the students, but also the university and the automotive industry sponsor. Through this capstone project, the experience has shown students the importance of communication, project-management, teamwork, innovation, and leadership which will have an impact their professional careers.

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