EFFECTIVE MANAGEMENT OF INDUSTRY SPONSORED SENIOR DESIGN PROJECT COURSE

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ABSTRACT

Senior design project courses in mechanical engineering are a challenging and important classroom experience for students often in their final semester of undergraduate engineering education. Senior design project courses are often structured to emphasize team work on projects initiated and/or sponsored by industry. Faculty involved in teaching such courses need to effectively manage the course offering and lead by example to students who are learning to manage their own projects. The Senior Design Project course in Mechanical Engineering at the University of Wisconsin – Platteville fits this profile wherein projects from diverse industries and companies are undertaken by student teams of four to six members. Projects vary quite a bit in terms of their nature and expected outcomes. When such variations are combined with the number of projects that range typically from five to twelve projects per semester, it sets up an excellent learning opportunity for everyone in the class. This paper discusses requirements imposed by the nature and number of projects, project expectations, and educational expectations of the course along with effective management strategies and methods used to meet the requirements. Specific examples of strategies and methods used in managing projects and educating students on key topics ranging from design processes to engineering management are provided. Methods used to assess students' performance as individual team members and as project managers as well as their learning of different topics of importance are also discussed.

INTRODUCTION

Mechanical engineering majors of today are challenged with the need to acquire a broad and yet good level of knowledge of various topics that are both technical and management related. The Senior Design Project course in the final semester before graduation needs to serve as the pathway and the proving ground for students to demonstrate their readiness to meet such a challenge in the workplace. To meet these objectives, the instructor of the course needs to effectively manage the course. This requires qualities of broad technical and management knowledge and experience, people and organizational skills, and leadership on the part of the instructor. This paper addresses strategies and techniques that can be used to effectively manage a Senior Design Project course in mechanical engineering. These are addressed within the context of the course centered on student team projects undertaken primarily from industry. The strategies and techniques have evolved over years of experience of the author in teaching the Senior Design Project course at UW-Platteville and an equivalent course at UW-Madison. The strategies and techniques are explained after discussing the purpose and objectives of the course. Sample examples of documents that support effective management of the course are provided.

PURPOSE OF THE COURSE

The main purpose of the Senior Design Project course is to provide Mechanical Engineering students with a design experience that is typical of what they will encounter in industry. The experience is provided within the framework of educational requirements. All of the projects are sponsored by external sources, typically industry. The sponsors almost always provide a project coordinator and in some cases equipment. The projects are *real* projects that can have practical implications for the sponsor. ***The goal is to satisfy the sponsor's expectations consistent with the educational requirements***.

OBJECTIVES OF THE COURSE

The specific objectives are for the students to:

1. Engage in creative engineering.
2. Apply fundamental principles to design.
3. Learn and participate in the dynamics of team effort and management.
4. Critically consider design alternatives.
5. Consider scientific, technological, social, ethical, economic, and environmental aspects of engineering as warranted.
6. Complete the project within time and budget constraints.
7. Practice oral and written communication skills.

PREPARING FOR THE COURSE

The Senior Design Project course is quite different in the logistical preparation and delivery when compared to most other courses in the mechanical engineering curriculum. The course requires a thorough preparation for the hectic first few days of the course followed by varying and busy conditions during the management of the course week to week all the way to the final week where things are again very hectic.

A few weeks before the semester begins at the very least, it is important to contact various companies in different industries and gather good projects that are relevant, educational, and feasible to be undertaken by a team of students over a semester. It is necessary for the instructor to establish a network of industry contacts and exercise good judgments in generating a list of projects. The number of projects so gathered can be about 25 to 50% more than the eventual number of projects that will be undertaken. Such an over-subscription provides students with a choice of projects to select from – something that the students are very receptive to. As is typical in industry, the project descriptions at the start range from a single paragraph to a lengthy document supplemented with specifications, drawings, and electronic files of solid models. The instructor needs to prepare the documentation about these projects. It is best to have a

package for each student or team that includes a numbered summary of projects on the top followed by description of each project. The project description portion of each project can be numbered as per the index in the summary first page for easy reference. The need to go to such detailed organization of documentation is because of the vast amount of information that students need to go through in a very short amount of time during the start of the semester. Besides the Projects' Description package, copies of the Course of Study, a Bidding Form for each team to bid on the projects, and a Student Schedule Table to help plan field trips to sponsors' locations need to be ready to be distributed to the students on the first day of class. The Course of Study documentation is very detailed (typically ten pages long) and contains information on the following:

* Class room and meeting dates / times
* Office hours of the instructor
* Purpose and objectives of the course
* Assessment and grading policy
* Team formation procedures
* Project Manager Responsibilities and Performance Evaluation Procedures
* Project initiation requirements such as travel to sponsor's location and Scope of Project
* Policy on bidding and assignment of projects
* Weekly reporting requirements
* Interim report and presentation requirements
* Final report and presentation requirements

The format and content of the Course of Study has evolved over years of experience of the author in teaching the Senior Design Project course. The document has been suggested as a useful resource as part of the recommendations of a report that presented the findings from an examination of several project-based courses at three universities in Sweden and one in the United States. The recommendations are for possible solutions to common barriers to teaching and learning in project based courses. The universities studied were the Royal Institute of Technology (KTH) in Stockholm, Linkoping University in Linkoping (LiU), Chalmers University of Technology in Goteborg, all in Sweden, and the Massachusetts Institute of Technology (MIT) in the United States. [1]

THE FIRST WEEK OF CLASS

There is probably no other course in the curriculum that demands so much on the first day of class. If the first day of class is well planned and executed, what will follow will be so much smoother. Following brisk introductions, brief description of the content in the projects' package is explained to the class on the first day. The students are then allowed to form their teams and gather each team at the circularly arranged seating. The projects' package must then be distributed so that each team can discuss the projects of interest and "bid" on the projects. The Bidding Form essentially seeks the top few project choices of each team. This enables the instructor to allocate projects to teams based on their interests as best as possible. The instructor of course needs to factor in other aspects such as relations with sponsors and need for continuing past projects in assigning projects. A Bidding form template is shown in Fig. 1.

ME 4930 SENIOR DESIGN PROJECT
BIDDING

Congratulations on forming a team! It is time for you to now "bid" for the project that you would like to work on! Follow the procedure below to complete your bid:

a. As a team, go over each of the project proposals carefully in a brisk manner. Discuss individual interests and capabilities, project objectives, team interests and capabilities, and the match between the project objectives and team objectives.

b. As a team, select any suitable rating method to rate each project. Each project could be given a team rating based on a method chosen by the team or by combining individual rating using a suitable method chosen by the team.

c. Whatever the method chosen in (b), you will finally have to, as a team, ***select three projects that are comfortable for you to work on as a team in decreasing order of importance*** and complete the following table. It is best not to lean too heavily on any one project but instead consider all your choices as equally preferable. (Remember that in the real world, we do **not** have the luxury to work on projects **we** alone like!). In the **first column** of the table, enter the **project number** that is provided at the top right corner of the first (or only) page of each project proposal. Enter the **title of the project** in the **second column**. ***Please remember that it is not a guarantee that you will be assigned any of the top five projects you have chosen! You understand that your professor has to decide the project assignments taking into consideration many different aspects. But you should also note that every effort will be made to assign at least one of the projects in the table below.***

PROJECT #	PROJECT TITLE

d. **Complete the following in alphabetical order of last names of your team members. Also, mark a * beside the name of the person who will be the first Project Manager.**

Name	Phone	E-Mail	Date	Signature
1				
2				
3				
4				

Fig. 1

Following the busy first day of class, the bidding forms help the instructor a great deal to assign projects based on considerations mentioned earlier. The information in the bidding form also helps the instructor to contact the project manager and in turn other members of any team at any time. The project assignments are formally announced to the class on the second day of class. The project manager is asked to contact the sponsor and arrange a visit to their facility to better understand the project problem. The instructor goes to as many of the field trips as possible with the students. Often, some field trips happen in the very first week of classes.

SECOND AND EARLY WEEKS OF CLASSES

Field trips of almost all teams are completed by the first two weeks (three at most) of classes. Delays, if any, are due to weather or unavailability of sponsor contact. During the class hours of the first few weeks, students learn the macro aspects of the design process models that will be used for the projects. Typical models include the Symmetrical Problem Solution Model of Nigel Cross [2] and the Mechanical Design Process model of Ullman [3]. The iterative nature and the ability to apply both a top down and a bottom-up approach to design through these models are emphasized. The detailed design process steps within these models are explained in subsequent classes. Teams start applying the design process steps and methods for each of these steps right after learning about them. For example, it is typical to learn about the design process step of clarifying objectives and the "Objectives Tree" design method in the first or second week. Teams prepare a draft objectives tree for their project soon after that. Typical design process steps that students learn and implement are (methods are given in parenthesis following the process step): Clarifying Objectives (Objectives tree), Establishing Functions (Function Analysis Flowchart), Setting Customer Requirements and Determining Engineering Characteristics (House of Quality), Generating Alternatives (6-3-5, Morphological Chart, Triz), Evaluating Alternatives (Weighted Objectives Table or Decision Matrix), and Improving Details of the final solution (drawings, solid models, finite element analysis, animation, prototype, testing, final report, and final presentation to name a few). It is very important to enable the students to work on every stage of the design process and methods both individually and jointly as a team. Strategies to enable this include the generation of individual and team template documentation both in hardcopy and electronic form; weekly submission of individual and team work on such documents; Weekly Progress Report submission by Project Manager; weekly meetings with Project Manager. It is important to ensure that the instructor uses the meeting with the Project Manager effectively so keep abreast of project developments and guide them without micro-managing the design decisions for them. The meeting must be well planned and should answer the following (a prepared form to note down points before, during, and after the meeting is highly recommended):

- What are the major project expectations? What is the progress-to-date on both the macro and micro aspects of the project?
- Are all expected submissions up-to-date?
- What is expected for next week?
- Information on project administrative logistics updated?
- Is feedback on progress-to-date given?

AROUND THE MID-SEMESTER OF CLASSES

Around the half-way point of the course, every team is likely to have arrived at a final concept for their project consistent with the Scope of Project agreed upon by the team, the sponsor, and the instructor. Teams also prepare an interim report and give an interim presentation around the half-way point of the course. An interim presentation evaluation by peers and faculty is used to provide feedback on their presentation performance. The evaluation is both semantic (written comments) and objective (numerical conversion of rated evaluations). The half-way point of the semester also signifies a shift in focus of discussion in class from design process/methods to engineering management topics such as engineering ethics, time management, and human information processing models.

THE FINAL WEEKS

The final week or weeks of the semester are again hectic just like the first couple of weeks of classes. During the final week, teams complete all detailed aspects of their final concept they arrived around the half-way point of the semester. These can range from detailed drawings to working prototypes, depending on the scope of each project. Teams also prepare their final report and give their final presentation to the class, sponsors, and invited faculty.

ASSESSMENT

A course such as Senior Design Project has a subjective element. To assess the performance of the students in such a course, especially under a team project environment, is challenging. It is important to provide an objective assessment of the performance as best as possible. This will demand considerable time and effort on the part of the instructor to set up the assessment procedures, to implement them, to analyze the gathered data, and to assess the performance. The strategy adopted is to first inform the students at the very beginning of the semester of the assessment breakdown. A typical breakdown is: Interim Report and Presentation weight of 20%, Final Report and Presentation weight of 50%, Individual Participation as a Project Manager and as a Team Member weight of 15%, and Homework/Quiz weight of 15%. The homework/quiz component includes on-line quiz on various topics such as design processes and methods, time management, engineering ethics, personality types, robust engineering, and design for manufacture. The interim presentation evaluation is both semantic (written comments) and objective (numerical conversion of rated evaluations). The Project Manager evaluations by team members are also both semantic and numerical. The Project Manager evaluations are given back to respective students to help them understand how their age group peers assessed them on various aspects of leadership. The final presentations are evaluated by the audience on several points such as organization, clarity, preparedness, engineering rigor, and soundness of solution. A numerical composite is arrived at from all these evaluations to assign student grades.

EXAMPLES OF SPECIFIC MANAGEMENT ASPECTS

We have thus far discussed some of the broader aspects of managing a senior design project course. There are of course many specific aspects that must be addressed with equal importance and emphasis. In this section, we will look at innovative approaches that could be taken to find projects from industry and address how students gain knowledge and problem solving skills by working on industry projects as examples of specific aspects.

FINDING INDUSTRY PROJECTS

Before acquiring projects from industry, it is first of all important to broadly establish the general parameters that characterize industry projects as being suitable for the Senior Design Project course. For example, projects must entail significant mechanical engineering design and/or fabrication and/or testing. The amount of work and the timeline to achieve it must be a semester long. If the project needs to go beyond that limit, the company should be made aware of that by the professor while discussing the project even before the semester begins. Although such decisions can be made (and are made sometimes) by the student teams after they take on the project, it is better to resolve as many decisions that could be transparent to the students as possible. The companies need to recognize that projects that involve expenses beyond a few hundred dollars for purchase of equipment, material, components etc will have to provide their own funding. After establishing such parameters, it is important for the instructor to contact companies well before a semester is to begin and start gathering projects. This can be a challenging task even for senior faculty. A strategy of establishing long-term relationships with many companies is most beneficial in this regard. Such relationships take time to establish and happen due to several factors such as the delivery of practical project results, serving as a university resource for other interests of the company such as temporary or permanent employment of graduating students and consulting services by faculty. It is also beneficial to engage company representatives in the project through activities such as having them meet with the students early on in the project and inviting them to attend final presentations on campus. During the final presentations, company representatives can formally evaluate the presentations and attend a luncheon to discuss project outcomes and the next steps if any. New industry contacts can be established by contacting companies through alumni who work there. Making unsolicited calls to engineering personnel of new companies found through literature search are another way to establish new contacts and projects.

HOW STUDENTS GAIN KNOWLEDGE AND PROBLEM SOLVING SKILLS THROUGH INDUSTRY PROJECTS

When students work on industry sponsored projects, one of the key learning experiences for them is the realization that such projects differ from classroom projects by the demands of *practical* high quality and low cost expectations that industry sponsored projects entail. Another key difference is the number of other practical constraints within which the industry project results need to be realized. Several of these constraints, and these could be many, are often technical in nature. Such constraints demand a

thorough application of appropriate design process and methods for every stage of the design process. Instructor's knowledge, teaching, and guidance regarding design processes, methods and strategies can be a valuable asset in the student teams embarking on the right design strategy and approach for each individual project. Industry projects, by the nature of demands placed by them, often enable students to be better team players. Elements of good team work such as leadership, communication, and understanding of individual personality types can be made more effective by formal discussion of such topics.

SUMMARY

This paper addressed effective management strategies and methods to meet the requirements of an industry sponsored team project based Senior Design Project course. Specific examples of strategies and methods used in managing projects and educating students on key topics ranging from design processes to engineering management were provided. Methods used to assess students' performance as individual team members and as project managers and in their learning of different topics of importance were also discussed.

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The reviewers ask that you make the following changes:
The paper could be improved if the author would provide some innovative approach regarding how to work with industries in finding the projects and detailed descriptions about how students gain knowledge and problem solving skills by conducting the project with examples.

BIOGRAPHY

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