A Curricular Model for a One Semester Capstone Course in Engineering

Mohamad S. Qatu[1] *and E. William Jones*[1]

Abstract – Universities are often challenged with having to deliver a capstone engineering course in one semester. This has advantages regarding course offerings and meeting graduation deadlines.

This paper presents a model for teaching the capstone course in mechanical engineering in one semester. It includes the necessary material to be covered in this class. In addition, it includes the necessary steps and components that should be addressed in this class. The proposed model will include an industrial based project with a condensed timeline. It also includes material on the engineering design process, design for ergonomics, ethical consideration, project management, peer evaluation, technical writing and presentations, conducting design reviews, design for cost and manufacturing as well as other subjects. The paper also addresses how these aspects can be implemented in an actual senior project. The paper will also address the challenges an instructor faces when offering such a class in one semester. These include the condensed timing, the scope of reasonable projects, team make up, and others.

Keywords: Industrial, capstone, curricular, model.

INTRODUCTION

A survey [Todd et al, 1] of capstone engineering courses in North America shows the high interest engineering educators have in the subject of senior projects. There is a wide variety of methods used by different schools in teaching capstone courses. One can find schools having senior projects conducted by one student or a group of students, i.e. teams. The students themselves, schools, or industries may sponsor projects. The need to include 'real world' industry sponsored design projects has been established [Black, 2]. Transforming the needs and challenges of the industry into the classroom prepares the graduates to compete in a current, challenging marketplace. The 'real world' experience presents most accurately the requirements of industry. Graduates should be exposed directly to industrial needs and understand economics and customers drive them. They should realize that a good portion of the engineering skills are dedicated to actually formulating the problem, which includes asking the right questions, in addition to trying to find a solution. Today's industry demands a production-ready graduate, rather than a graduate who will still need some further training. While the survey paper mentioned earlier [Todd, 1] described different modules and a broad range of opinions on how to organize and operate senior project capstone courses, a reasonable limited treatment is found in the literature on one-semester based senior projects.

Other works describe a partnership with industry in conducting senior projects as compared with projects emphasizing design only [Uddin, 3; Anderson, 4; Todd et al, 5, Catalano, 6]. Such partnership may vary: industrial based senior projects; senior projects that are partially supported by industry; just having industrial representatives on the review panel at the senior project presentations. Todd et al [7] described multi-disciplinary teams being created and taught a structured development approach to produce typical industry deliverables. Others also have researched multidisciplinary senior projects [Fornaro et al, 8, Neumann and Woodfill, 9]. Conn et al. [10], and Ruud and Deleveaux [11] presented models for industry-sponsored capstone design courses.

[1] Professor, PO Box 9552, Mississippi State University, MS State, MS 39762, qatu@me.msstate.edu

Among the recent works that describe how industry can be involved in senior projects, the work of Bergman [12], Maffia [13], McDermott et al. [14] should be mentioned. They reported the application in various engineering disciplines. Daniels and Aplund [15] described an industrial project work in a one semester course. Celmer [16] described a project sponsored by both industry and community on noise control.

Qatu et al [17] discussed a significant step towards getting industry involved with engineering education. The projects are suggested, funded, and finally accepted by the industry.

This work describes an experience of the author with a one semester capstone course. The industry itself can be the leader in determining the goals, the acceptance criteria, and the project requirements. In addition, possible projects are drawn from the Society of Automotive Engineers Formula SAE teams. Communication with the faculty is vital to ensure a total success. The faculty advisor is a coach, consultant, and evaluator of the students. He must work closely with industry to decide on the nature of the projects and to make sure that the student skill mix is able to handle the project(s). In the setting suggested here, failure is not an option and the student team must deliver, even if graduation date is to be sacrificed. Personal experience shows that this is rarely the case, but the point should be clearly made to the graduating student, that the marketplace would not permit a less than perfect job if one is to succeed and endure fierce competition. The faculty advisor should monitor the project very closely to assure on time delivery.

The course should be delivered in an industrial setting, with industrial-type standards, and with expectations, that should be set and met. This issue is of fundamental importance and provides the framework for setting directions and implementation of industrial based senior projects. In real-life industry, a grade of 'C' (or even an "A-") is usually not acceptable. More often, a task is redone until it is done correctly. The successful completion will ensure that students graduate with confidence in their abilities. The faculty must do everything possible to help them succeed. Industrial based senior projects should emphasize communication. Both written and oral forms of communication are put into the industrial setting.

GROUND RULES

The ground rules for a capstone-engineering course are listed below.

1. The project should mimic an industrial setting. The industry can determine the project, expected outcomes, and available funding. The faculty members evaluate the scope of the project, determine the personnel requirements, selects and builds the teams to perform the project.
2. Students must complete the project to graduate. This insures developing a commitment to success in the minds of the students. A failure grade based on not completing the project is simply unacceptable. If the project is not finished on time, all students will receive an incomplete grade and will not graduate. Such action can only be reversed if the team completes the project at hand. This means that the only criterion used to fail a student is his/her failure to cooperate and contribute to his/her team. A procedure must be developed for removing an individual, who is not completing their assigned tasks, from a team as early as possible. This procedure can begin with an oral discussion between the student and the faculty advisor. If behavior has not changed as a result, a written warning will be delivered to the student. Finally, if the student fails to respond, removal of the student should take place. Students must learn how to work together and solve their personal issues.
3. Every effort will be made to build teams that are multi-disciplinary. Most engineers in industry must deal with other professional and technical personnel from different disciplines on a continuous basis [Hamilton, 18; Gorman et al, 19].

4. In rare situations, projects may be dismantled and team members can be redistributed if the industrial support or student skills do not prove to be up to the challenge or the problem at hand does not show enough merit. Such actions are not viewed as failure, but as a re-organization effort on part of the faculty. Ideally, dismantling projects and redistributing team members should not be delayed beyond date for the team's presentation on the project scope.

THE CURRICULAR MODEL

Preparatory Work

The first step in building engineering capstone courses based on industrial projects is to invite local and regional industries to send potential needs suitable for senior projects. Faculty members require certain information from industry in order to determine how suitable these potential problems are for senior projects, the number of students in the team necessary for performing the project, and to identify the skills, facilities, software and hardware required. In addition, requests are made to on-campus teams (e.g. Formula SAE teams) to propose these projects for the senior project class to help their own task. The Industrial Engineering capstone engineering teams have used ME Teams as consultants for redesign or test of products evolving through their product realization process. (The ME Teams are included in the initial brainstorming part of the IE Team's planning process to identify tasks which may contribute to manufacturability, safety, enhanced product value, etc.) The Formula SAE Car Teams use the ME Teams as consultants for design of components or systems. Examples of these are to have a finite element analysis of the complete chassis system of the formula car; or analyzing the wheel uprights in the formula car; redesign of a component to facilitate manufacturability for the IE Team.

• *Project summary and description*. This describes the need, requirements, priority, and timeline and budget information about the potential project. It also includes background information, design, manufacturing, and process criteria.

• *Project outcome expectations*. This describes the final outcome expected from the project including whether the project is classified as: research; design only; research with a prototype build; or design and build. A statement about the criteria of success for the project should be included.

• *Industrial contact*. The name, title, address, phone numbers, fax number, and e-mail address of an industrial representative should be provided.

• *Industrial support*. This includes the budget, manufacturing support, as well as material and equipment support the industry is willing to devote for the potential project.

Work Done by the Teams

The students and faculty are expected to perform certain tasks. Descriptions of these tasks are listed below.

1. Creating teams. This is probably the most involved process for the faculty during the first semester. Knowledge about graduating senior students, which must include assessment of their strengths and weaknesses, is essential for creating the right team for each project. The industrial and managerial experience of the faculty is also critical. The process ends after determining: the projects to be performed; the team individuals for each project;, the faculty advisor. This step has to be completed by the end of the first week of the semester. Other aspects of teams and team building are discussed [Miller and Olds, 20; Tarricone, 21; Thacker, 22; Margerison, 23; Woolf, 24; Robillar et al, 25].

2. Proposal: The teams are asked to conduct detailed research about the project problem at hand. This occurs early in the semester. By the end of the 3rd week of the semester, a formal written proposal is submitted to industrial contact.

> a. During the first three weeks, lectures on team building, cost analysis, project management, communication, and performance evaluation can be delivered.
>
> b. The advisor returns the graded proposal to the team within one week. The team will then revise the proposal and send the revised copy to the industrial contact, with a copy submitted to the faculty advisor. It is the responsibility of the industrial contact to approve the proposal. This should not take more than one week.

3. Design review(s)/update presentation(s): The faculty advisor and the team will also be involved in a detailed design process. The project is divided into various components, and for each component a design review is conducted. This includes informal to semiformal presentations made by the students involved in designing the components being reviewed. At least one design review/update presentation should be performed by the 8th week of the semester. The design review is critical as it serves as a check to assure that all constraints, forces, scheduling, etc. are correctly included in the process in order to assure that the team and each team member are progressing on in a meaningful way on schedule.

4. Final Presentation: By the last week of the semester, the students are required to conduct a formal final presentation similar in requirements to the previous update presentations. (An informal review of the final presentation by the Faculty Advisor two weeks prior to the formal presentation may serve as a filter, which will significantly improve some presentations.)

5. Final Report: At the end of their presentation, each team must hand in a final report about their project, which typically includes operation manuals, specifications, and other information. A memo has to be sent to the faculty, the faculty advisors, the industrial contact, and to the Dean inviting them to the presentation. Modifications to the above sequence can be made to accommodate certain issues that relate to a particular situation. For example, the faculty may request two update presentations instead of one, two peer evaluations, or other requirements as they see fit.

6. Performance evaluation. A critical piece of building a successful team is acceptable performance of every team member. In addition, it is recognized that most engineers will have to evaluate others at a certain point in their career [23,24]. For these reasons, peer performance evaluation is conducted of each semester. Every student is asked to evaluate every member of his/her team both in writing and orally. The written portion will be handed to the faculty advisor after the oral evaluation. In this exercise, each student is evaluated by the faculty advisor based upon how well they performed the evaluation of their other team members and not on what other members say about his/her performance. This is based on the professionalism, the depth of the evaluation, and finally the specific examples used to support the evaluation. The objective of peer evaluation is to emphasize the objectivity, thoroughness, and fairness when evaluating others. These evaluations serve the main purpose of bringing team member performance out into the open.

DEPARTMENT AND FACULTY SUPPORT

Each team will need university support for the completion of their senior project. The secretarial staff and the faculty of the departments or school are the focal point. The interface with the secretarial staff is typically in the areas of copying, external communication, and room utilization/scheduling. The student teams are instructed to follow certain guidelines in their interface with the secretarial staff. Students are instructed to consider themselves as guests in the office area.

1. A faculty advisor. The fundamental rule of the faculty advisor is to act as a coach and evaluator for his team. Various faculty members have different visions for their rule. Some see themselves as consultants to their team allowing potential leaders to emerge within the team as the project progresses, while others assume the leadership of their teams. The system allows for diversity of faculty visions on how they conduct themselves with their teams. The basic functions of evaluating and coaching should be a part of their vision. The amount of leadership given to the team or assumed by the faculty advisor also depends on the project. If the project has a high dollar value, fixed outcome and is falling behind, or getting off track, the advisor should step in and assume more of a leadership role. Multiple new projects may easily exceed the faculty advisor's allotted time for the course. However, repeating prior projects may rob the student of the more creative experiences, which a new problem delivers.

2. Telephone, fax, e-mail and mail support. Students may make long distance telephone calls, which are directly related to their senior projects from a designated telephone in a designated room. The students are instructed to leave the room as soon as the call ends allowing others to use the telephone. Similarly, student teams may send mail or faxes by completing a cover sheet and leaving the fax or mail item in the department-outgoing mailbox.

3. Photocopying and transparencies. The department or school will make photocopies or transparencies that directly relate to the senior projects. The team should complete a photocopy request and leave it in a designated photocopies box. Students should plan ahead of time and should not expect immediate service.

4. A designated room. One room on campus will be designated for senior project students to conduct their meetings. A scheduling book must be available in the department. Each team may schedule up to four hours per week in the room. The room is available for students during after-hours.

5. Workshop area. Teams may ask for a certain area in the workshop to be devoted for their senior project. Students manufacturing or assembling their project need such an area. Limited accessories may be provided to the students. The students may also request the use of certain apparatus, tools, machines, etc. in the workshop area and ree required to agree to follow the safety procedures provided by the school.

CHALLENGES AND CONSIDERATIONS

Some of these are listed below

1 Team teaching. Because of the various industrial and managerial expertises of the faculty members in any department, the authors believe that the senior project course should be a team-taught course. This includes the lectures of the first part of the course as well as deciding various policies and procedures for the whole course sequence.

2 Faculty times. Industrial based senior projects require considerable time and commitment from the faculty, department, as well as the university. Faculty members who are involved in senior projects have to spend at least 2 hour per week meeting with their teams to insure their progress. The faculty members involved in senior projects may have reduced university service duties, and be considered for industrial or sabbatical leaves more often.

3 Industrial/Customer participation. The faculty needs to actively work to keep the industrial contact informed and involved. Regular communication and interface with this individual is critical to project success. The industrial contact should attend all formal presentation and design reviews.

4 Legal issues. Several legal issues have to be considered by the faculty. For these issues, the university's legal team should be consulted. Among these are issues of liability to the students who will work on products that can be commercialized. The legal documents should cover both students and the university from a potential lawsuit from the industry or its customers. Confidentially of company information and intellectual property may be issues in some cases.

CONCLUSIONS

An effort in the open literature on a one semester, industrial based, senior projects is described. The experience is found to be fruitful in graduating engineers who are ready for the demands and competitiveness of industry. Certain challenges will be faced when industrial based senior projects are handled. The level of these challenges will depend on type of project, time frame, and financial support received by the industrial firm on the project. The administration support to the faculty members, the industry and the students are vital for the success of industrial based senior projects.

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Mohamad S Qatu

After spending 12 years in industry, Dr. Qatu returned to academia to teach courses and conduct research. He is the author of 4 books, 60 refereed articles, 2 patents and several other publications. He is a Fellow of SAE and ASME.

E. William Jones

Dr. Jones spent much of his career ar Mississippi State teaching mechanical system design and other courses. He also developed many courses over the years, advised many students and conducted consulting with many industrial firms.