AC 2007-2486: MANAGING SENIOR PROJECTS: EDUCATING GRADUATES AND UNDERGRADUATES IN A SENIOR PROJECT COURSE

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Managing Senior Projects – Educating Graduates and Undergraduates in a Senior Project Course

Abstract—All seniors in computer, electrical, and mechanical engineering at __________ University take a multidisciplinary senior design course. In the first week of the Fall semester, students are assigned to teams (based on their ranked preference), and each team is then given a project that contains both electrical and mechanical aspects. Some past projects have included competing in national design competitions, developing a student entrepreneurial project, creating a prototype for industry, advancing a National Science Foundation sponsored research project, or helping people in developing countries. Teams are typically made up of two to three electrical/computer engineering students and two to three mechanical engineering students. All teams have a primary advisor from one discipline and a secondary advisor from another discipline to balance the expertise available to each team. The structure of the course follows the design process from conception to a computational model of the design to the creation of a physical prototype. The loop is closed by requiring each team to test their prototype based on design requirements developed earlier in the design process.

In the summer of 2006, the College of Engineering and the College of Business Administration offered their first course in a new Master of Engineering Management (MEM) program. A unique aspect of this program is the MEM 625/626 course sequence. In this pair of courses, MEM graduate students become project managers for the senior design teams in the undergraduate, multidisciplinary senior design course described above. This has had numerous benefits for both programs. Undergraduates are now given an experience that more closely resembles that which many will find in industry upon graduation, while the graduate students are given a chance to practice the project management skills learned in their own coursework.

This paper describes the decisions made during the process of incorporating the graduate students into the undergraduate, senior projects course, the benefits of these choices, and the lessons learned throughout this process.

1. Introduction

The engineering graduate of 2007 must demonstrate a wide variety of expertise, ranging from foundational knowledge in mathematics and science to critical thinking, creativity, design expertise, and communication skills. In addition to these abilities, it is becoming apparent that knowledge of business and management skills is also essential for the career-long success of an engineer.[1-4] Engineering management can, in fact, be considered its own discipline, and a number of universities offer specific engineering management degrees that help students prepare to become both technically skilled and knowledgeable about managing other engineers in a professional setting.[5-9] Even within traditional engineering programs, the importance of engineering management is emphasized in a variety of settings, including senior design projects[10-12] and undergraduate research programs.[13]

With the ever-increasing curricular pressures on undergraduate engineering programs, it is difficult to see how significant engineering management could be incorporated without necessarily decreasing the emphasis on other areas of importance.[14] Such decisions should be considered seriously and made in the context of the learning objectives of the program.[15] One possible solution to this challenge that is gaining in popularity is an undergraduate degree in engineering followed by a graduate degree in engineering management.[16-23] A Master of Engineering Management (MEM) degree allows the students to first develop a solid technical background in their undergraduate programs and then focus on engineering management issues either immediately in a fifth year of college or later after they have been in the workforce for a few years.[24] Such graduate programs in engineering management share some similarities with Master of Business Administration (MBA) degrees, but they are specifically crafted for students who have an engineering background and a desire to manage engineering teams.[25-26] Teaching such a program effectively can be very challenging, requiring extensive professional development by engineering faculty and close collaboration with faculty in a College of Business Administration.[27-28]

At the same time, the most successful engineering graduates typically exhibit a strong entrepreneurial spirit, whether this spirit is reflected in starting one's own business or in taking responsibility for one's own career success in a larger corporation.[29] The skills required of an entrepreneur closely mirror those required by the engineering accreditation process, [30] especially the ability to work effectively on multidisciplinary teams [31-34]. Furthermore, entrepreneurial skills have been shown to promote engineering management skills,[35] ethical thought processes,[36] and engineering design.[37-40]

The engineering faculty at ______ University have worked diligently over the past decade to continually improve the senior design experiences offered to its engineering students.[41-44] In this paper, we will address the most recent improvements made to the course during the summer of 2006 and during the 2006-2007 academic year, integrating engineering management and entrepreneurship by including MEM students as project managers on half of the teams while using the other half of teams as a control group.

2. Master of Engineering Management Program Description

In the summer of 2006, the College of Engineering and the College of Business Administration offered their first course in a new Master of Engineering Management (MEM) program. This program has been designed specifically to provide engineering graduates with the business skills they will need for successful careers. One emphasis for the program is a focus on values-based leadership skills that will prepare graduates for engineering project management positions.

A unique aspect of this program is the MEM 625/626 course sequence. In this pair of courses, MEM graduate students become project managers for senior design teams in the undergraduate, multidisciplinary senior design course described in the following section. A later section will discuss some of the choices that were made for the integration of these students into an established course sequence that has been optimized over the past decade and has historically been extremely successful.

To prepare MEM students for the MEM 625/626 course sequence, students are required to take a graduate level project management course before the start of the fall semester. This course, MEM 605 Project Management, emphasizes the importance of technical skills, communication skills, and interpersonal skills in order to assume leadership roles in project management and product development. MEM 605 is a seminar-based course that provides an open atmosphere, allowing for multiple discussion opportunities and guest speakers that can provide students with real-world contexts to supplement traditional textbook knowledge.

3. Multidisciplinary Design Projects at ________ University

The capstone senior design experience for Mechanical Engineering (ME) and Electrical and Computer Engineering (ECE) students at _________ University has rapidly developed into one of the most valuable learning experiences for the undergraduate students. The course sequence covers two semesters and provides a multidisciplinary, team design experience to students in both the mechanical and electrical/computer disciplines. Prior to the 2000-2001 academic year, both the ME and ECE departments had an independent senior design sequence. In the summer of 2001, these were merged by the ME and ECE departments, and this has continued to the present.

The senior design curriculum change was motivated by a need to place additional emphasis on developing student skills in product design and effective multidisciplinary teamwork. Much curriculum development at our university and others has focused on these skills since the introduction of Engineering Criteria 2000 by the Accreditation Board for Engineering and Technology. Additionally, multidisciplinary design and teamwork have been active areas in curriculum development at other universities.

Each team of four to six students (including at least two students from ECE and at least two students from ME) are assigned a primary advisor from either ECE or ME. A professor from the other discipline serves as a technical advisor, but does not advise the team on a week-to-week basis. Students meet with their advisor for a 50-minute session once per week to report on their progress and receive guidance on how to deal with the challenges they face on the project. In addition, there is an all-course weekly meeting that is 50 minutes in duration. During this meeting, professors deliver lecture material or students give oral progress reports.

The assignments throughout the two-course sequence are intended to impart the engineering design process to the students. Early in the fall, students produce a document outlining the system design requirements defining the measurable outcomes for success. Students then generate three alternative solutions and evaluate an optimal solution based on a quantitative tool. By the end of the fall semester, students develop an electronic prototype, verifying their design through computer tools such as CAD and PSPICE. By the end of the second semester, students have designed and constructed a prototype based on measurable criteria and will have tested this prototype to ensure that it meets these criteria.

An important aspect to focus on for the purposes of this paper is the interaction between the faculty advisor and the student group. The advising meeting typically consists of a report on the status of the project by the student team leader, followed by individual reports by each member on his/her personal progress. Finally, challenges facing the team are presented, and under the advisor's direction, the team sets the goals for the next week. In this capacity, the advisor acts as a direct manager, as well as the grader of their work.

4. Incorporating Project Managers into Senior Projects

The senior design course sequence has gone through many improvements in recent years, and has proven to be an invaluable course for our students. Following a series of planning meetings and considerable discussion it was decided that the integration of MEM students as project managers into the course would result in numerous benefits for both the seniors and the graduate students. During the planning process, extreme care was taken to ensure that any changes made to the senior design course would only enhance the student experience and not cause any negative effects. Not surprising, there were many challenges encountered when planning for this latest revision of the course.

Defining the roles of the MEM students was the first step in planning the integration of project managers into the senior project course. Although all MEM students have technical expertise in electrical, computer, or mechanical engineering, the decision was made to not allow them to perform any technical work or make unilateral decisions about the project design. The purpose of MEM 625/626 is to give the graduate students the opportunity to manage a project in a controlled environment. Since many of the graduate students may have recently completed their senior capstone experience, it is important that their role is restricted from simply repeating that experience. Therefore, realizing the MEM student will have technical expertise beyond that of the seniors, teams were encouraged to take full advantage of this knowledge and MEM student's technical role was limited to that of an advisor. The ideal authority of the MEM students falls halfway between the faculty advisor and the undergraduate team leader. In this sense, the faculty advisors have taken a half step up from their previous roles and the undergraduate team leaders have taken a half step down in their level of responsibility.

Administratively, faculty members in the senior design course also grade the MEM student's performance. The additional faculty work of grading the graduate student is balanced by the expectation that the MEM student's work will slightly decrease the advisor's work with the project team. The MEM student's grade is determined, in part, on specific deliverables. Some of these deliverables are one-time assignments covering the entire scope of the project, i.e., an analysis of the stakeholders involved in the project as well as a responsibility matrix for each stakeholder. Others are regular, weekly responsibilities, such as maintaining a detailed schedule of performance and budget for the team. The budget includes a means of tracking internal costs by "charging" for consultation with faculty (including the team's advisor) and for using facilities such as the manufacturing lab. This is done to model the costs that many companies will realize during a project. Teams are not actually charged for these services, but they are included in the MEM student's budget for the project.

Administration of the weekly meetings with all of the team members (senior design students, project manager, and advisor) are also the responsibility of the MEM student. The faculty advisors' "half-step up" means they now evaluate how the graduate students lead the meeting as opposed to leading the meeting themselves. MEM students must develop the agenda and meeting minutes as well as ensure that the meeting stays on schedule and that important information is communicated to the advisor.

MEM students also have the responsibility to evaluate their teams on a regular basis in a weekly report and in a final team evaluation. The graduate student's performance is evaluated based on the quality of their feedback to the undergraduate students and on the feedback they provide on the undergraduate students' written work and oral presentations. Senior design teams have large reports to complete once each semester as well as two important presentations. For the documents, a copy is provided to the MEM student to evaluate while the advisor grades the report. Once the advisor has evaluated the report, the graduate student's feedback is assessed by the faculty advisor to determine their performance of the MEM student as a manager. Oral presentations are also evaluated by the MEM student and the quality of these evaluations is also assessed, by the faculty advisor, in the overall review of the graduate student.

5. Benefits of the New System

The benefits of this endeavor impacted the undergraduate students, MEM student, and advisors. Undergraduates were given an experience that more closely resembles that which many will find in industry upon graduation, while the graduate students were given a chance to utilize the project management skills they learned in their own coursework. Advisors benefit from a change in level of management as well as the perspective gained from the addition of a project manager.

Though undergraduates typically did not appreciate (or even realize) the extra dimension that the MEM student provided, it did indeed exist. Typically in a senior design course, students face quite a contrast from their normal lecture/homework/exam-based courses. The nature of the work is open-ended and unstructured. It is precisely this environment that often causes students to struggle, while instructors realize that it is imperative for their future success. In this vein, the MEM student added more complexity to the course, and this resulted in both a broader and deeper experience for the students.

The experience of managing a team is the inherent goal of the MEM 625/626 course, and is a direct benefit to the MEM student. In the same way that the undergraduate students are typically not familiar with an unstructured course and profit from the struggles of overcoming it, so too the MEM student gains a trial by fire when she/he is thrust in front of five undergraduate students and asked to assume a leadership role. An often repeated salve to the consciousness of the instructors is that we wish for students to make their mistakes here rather than on the initial stage of their professional career.

One advisor comments that the addition of an MEM manager brought a stark contrast to his own leadership style. The instructor had a high-level "get things done" attitude, whereas the MEM student had more of a detail-oriented "how will we implement this?" style. Though this at first created a bit of dissonance with the group, it eventually led to an appreciation of the benefits of the alternate style for both student and instructor. It also gave an added depth to the student teams to see that not only are there different leadership styles, but that they will have to be able to deal with both types (and more) in industry. It is largely these sorts of real world "issues" that give students a rich experience in preparing them for industry.

6. Lessons Learned

As with any initial venture, the bad comes with the good. Even in the first semester, the instructors identified several key improvements to augment the experience for students in the spring semester of the two-course sequence. These revolved primarily around communication and organization.

In the second half of the academic year, the faculty advisors set a one-hour meeting time for all MEM students and all MEM faculty advisors. In this meeting, each MEM student gave a report of their team's status using an industry-standard form for progress reporting. This provided continuity across groups, feedback from other advisors for a particular group, and a sense of accountability for each MEM student, who had to appear before both peers and all faculty advisors. It also provided a check for progress in groups and a sense for MEM students that they were synchronized with their fellow students. This extra meeting time has proven to be very effective.

Another lesson learned involved direct communication between MEM student and advisor. In the second part of the course, each advisor had an individual meeting with his or her MEM student to give feedback to the student and to discuss strategies in managing the group. This proved to have two effects. It gave immediate, direct feedback to the MEM student, and it also insured that the advisor and the MEM student were on the same page. In this way, the one-on-one meetings reduced the likelihood that the MEM student and the advisor would give conflicting messages to the undergraduate team.

7. Conclusions

The integration of engineering management graduate students into an undergraduate capstone design course has been a unique challenge at all levels. The experience described in this paper was the first offering of the senior design course that incorporated MEM students. It provided an opportunity to study the changes that were made and provide the feedback necessary to improve subsequent iterations of the course. As in any significant change to a course, it is an on-going process. However, during this process, the faculty members involved in the process have learned a great deal and are encouraged by the benefits this initial trial has brought to both the undergraduate and graduate students. While an insufficient amount of data exists to determine quantitatively if these changes have been a success, the lessons that have been learned will allow the faculty to improve two experiences that __________ University is proud to offer.

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