Re-Engineering the Senior Design Experience with Industry-Sponsored Multidisciplinary Team Projects

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Abstract

Engineering education is changing in response to the significant technological and organizational changes in industry. One area of significant change in recent years has been undergraduate senior design projects. This paper provides a brief overview of the changes in the senior design project experience at Lake Superior State University with a special emphasis on the use of multidisciplinary design teams and the interaction of the faculty and student team with the industrial sponsor.

Introduction

Engineering educators are concerned about the rapidly changing industrial environment and resulting changes that are needed in engineering education. This concern is reflected in a recent American Society for Engineering Education (ASEE) major project report "Engineering Education for a Changing World."[1] This report calls for engineering education to not only teach the fundamentals, but to develop team, communication, and leadership skills and have a multidisciplinary perspective (Action item 4). This concern is also demonstrated by a recent American Society for Mechanical Engineering (ASME) report, Product Realization Process (PRP).[2] This report lists several skill areas that are needed in engineering education, and calls for engineering education to include the development of both fundamental and soft skills.

When significantly changing engineering education there is value in considering a re-engineering approach. Re-engineering, much like Total Quality Management (TQM), is concerned about changing processes to provide performance improvement. While TQM emphasizes continuous improvement through incremental change, re-engineering focuses on "the fundamental rethinking and radical redesign" of processes to achieve dramatic improvements in performance measures.[3] Re-engineering does not try to fix a process, but rather reinvent or dramatically change the process in order to provide improved results. The re-engineering change occurs by focusing on issues of purpose, culture, process, and people that are critical to the process being improved.

This paper discusses the re-engineering of the senior design project courses at Lake Superior State University to include multidisciplinary teams working on industrial sponsored projects. The paper outlines the nature of the changes with a focus on the multidisciplinary teams and the interaction of the faculty and student teams with the industry representative. A typical senior project is also presented.

Re-Engineering the Senior Design Project Courses

The engineering and technology programs at Lake Superior State University require a year-long senior design project experience. The purpose of this experience is to prepare students for the transition to industry by developing professional "soft skills" while strengthening fundamental engineering skills. [4,5] The paragraphs in this section will provide an overview of the dramatic change from discipline-specific group projects to industrial-based projects that use multidisciplinary student teams.

The use of senior projects initially started in the automated manufacturing engineering technology program, and then later in the mechanical program. These programs had developed automation processes and product design projects of significant scope and breadth. As a result of the quality of the projects, one student, Derrick McCaig, won the ISA Student Paper Award for a paper on his group's project, "Flexible Automated Assembly of Makita Cordless Drills" in 1994. The changes to the mechanical program were soon followed by the electrical program adding year-long senior projects with the assistance of grants from the National Science Foundation.[6,7,8]

Although quite extensive and impressive, these original senior projects only involved groups of students and faculty from the specific engineering disciplines. The student groups worked on projects that they and the faculty specified. Their projects were internal to the university, and did not require interaction with external agencies. These types of projects were similar to other courses where the students work to satisfy the instructor who is both guiding their work and defining the desired outcome.

About two years ago, faculty from the automated manufacturing, electrical, and mechanical programs started working together to make significant changes to the senior design project experience. With the goal of the project experience being to prepare graduates for the transition to industry, the faculty created a common year-long experience that would focus on real industry-based projects. Because of the desire to produce an industrial quality process or product design, the projects required the participation of students from several engineering areas. This dramatic change from discipline- specific internal projects to multidisciplinary industrial projects required that the faculty address issues of culture, process, and people relative to the senior project courses. These issues are explained in the next section that outlines the courses and describes the student and faculty teams.

Revised Senior Project Courses

The purpose of the senior design experience is to prepare students for the transition to industry by developing their confidence, and strengthening their engineering and soft skills. This revised senior design experience involves a year-long sequence where the multidisciplinary student teams work on industrial sponsored projects. The project courses are taught by a multidisciplinary team of faculty which is called the Senior Projects Faculty Board (SPFB). The following paragraphs will discuss the student and faculty teams, the culture of the senior experience, and the project completion process.

Student and faculty teams

The senior design experience is truly team taught. The SPFB is responsible for the administration, development, organization, and presentation of the project courses. The board has a regularly scheduled meeting each week and additional meetings as needed. One faculty member serves as a course coordinator, providing leadership for the faculty team, and another serves as a secretary or recorder. All faculty share responsibility for activities associated with the course, and participate equally in SPFB meetings, where decisions are made by consensus. Although one faculty member is assigned as an advisor for a specific student team, the faculty as a team oversees the progress of all the projects.

Typically the students are seniors majoring in engineering or engineering technology. One computer science student also participated last year. The students are assigned into teams of three to ten students. Although there are several methods for placing students into teams [9], the faculty place the students after discussing the needs of the project and each students personal strengths and characteristics.

Culture

The culture of the new senior experience is one of teamwork, professionalism, and success. The students do almost all of the course activities as a team, and almost all of a student's grade is based on team grades for the various assignments. The students participate in team building exercises, and select a team name, logo, and letterhead that are used throughout the course. They develop team norms and expectations that dictate internal and external team behavior which also helps the members develop as a team. The students also participate in peer evaluations where they evaluate the other team members both orally and in writing.

Professionalism is emphasized in all communication that the student team has with the SPFB, with the faculty advisor in team meetings, and with the industrial representative. Formal business memos are used for communication between the faculty board and student teams. Examples of memos include scheduling presentations, meetings, and design reviews, and arranging contacts with vendors and the industrial representative. The teams give formal presentations each semester which require business attire, quality overheads and handouts. Team meetings with the faculty advisor follow a business setting with a published agenda. The team members take turns leading the meetings, which include a review of the project timeline (schedule) and budget, and presenting their action items. Success and project completion are expected and driven by the industrial contact's expected outcomes. Completion of the project is required for passing the course. The student teams are guided towards success by the faculty advisor and faculty board throughout the year; however, the members of a student team will receive an incomplete until their project is acceptable to the industrial contact, faculty advisor, and the faculty board.

Process

The senior design process covers both fall and spring semesters. The fall semester is used for team building exercises, the development of project related skills, and defining and planning the project. The specific course activities in the fall semester include: team norms and expectations, creative problem solving, ethics, timelines (project scheduling), peer evaluations, research techniques, Total Quality Management, professionalism, and oral presentation techniques. The project activities during the fall semester include meetings with the industrial contact, giving an oral scope presentation, and doing all the preparation work for the project. The scope presentation at mid-semester is where a team demonstrates that they understand the customer's needs and expectations. At the end of the semester each team submits a formal written project proposal. The proposal includes timeline schedules, responsibility charts, budget and organizational plans, and a description of resources that will be needed from the university and the industrial contact.

The spring semester is used for completion and implementation of the project. Work starts by revising the project proposal and receiving a formal approval from the industrial contact. The teams meet twice weekly with their faculty advisor, and have several semi-formal design reviews throughout the semester. Each team gives a formal up-date oral presentation at the mid-point of the semester. At the end of the semester each team demonstrates completion of their project, often by meeting pre-established acceptance tests that are specified by the industrial contact. The teams give a formal presentation to a large, general audience, and provide the industrial contact and faculty advisor with a final project report.

Industrial-Based Projects

The philosophy of the projects is that each project addresses a real industrial process or product design. The industrial representative defines the specifications for the projects. The company provides all required funding for materials and supplies, and then acquires the completed project along with any patent rights. The student team designs and builds the product to meet the industrial contact's acceptance criteria. The student team works with vendors and manages a real dollar budget with a typical range from $3,000 to $50,000.

The initial projects were solicited by approaching industrial representatives who had a good relationship with the engineering department, such as industrial advisory board members and alumni. Because of the success of the projects the first year, it has become much easier to find projects and the faculty board is now in the position of selecting the projects from a list of proposals submitted by various industries.

The projects originate with a short proposal from the industrial representative. This proposal generally outlines the project need and desired outcomes. The student teams visit the industrial site and maintain communication with the industrial representative during the year to ensure that their project plan is consistent with the company's expectations. The students, university dean, and industrial contact complete legal documents that absolve the university and students from liability and transfer potential patent rights to the company.

As in industry, success is expected and the appropriate effort is given until success is achieved. The project is not considered complete until it meets the expectations of the faculty advisor, faculty board, and the industrial contact. The industrial contact is kept abreast of progress through regular weekly communication from the student team, by attending the scope and update oral presentations, and by reviewing the project proposal.

Typically the students must manage the purchasing of various hardware and software. This is usually accomplished by utilizing the industry's existing purchase order system. Often quotes from multiple vendors are required by the company. Additionally, students must work with third parties for the fabrication of unique fixtures and equipment that is needed for the project.

The type of project that works best is one with clear outcomes, especially if it represents a true and pressing need of the industrial contact. This could be a design-and-build project or automation process that the industrial contact needs by a specific date. This type of project provides the students with real-world challenge that simulates their first project in industry. It is important that there is clear communication among the student team, faculty advisor, and the industrial representative. It is also important that the industrial representative be familiar with the product application, and also be in a position to authorize the spending of appropriate funds for the project.

Example Project

Last year, the faculty board initially selected eight projects, and placed about 50 students into eight design teams. After a few weeks, the faculty cancelled one project and reassigned the students to other teams because that project did not represent a significant challenge. Some of the projects the SPFB selected include the automation of an assembly process for a company that builds drill index boxes, the design of an application software product for an electric utility company, and the design and building of a machine to test parking brakes after they are assembled. The following paragraph provides detailed information on the parking brake tester as an example of the complexity of the projects.

The end-of-assembly-line parking brake tester performed attribute and functional operation tests on parking brakes after assembly. The project started with a proposal by the company that listed operational and physical specifications. The faculty board selected a team of eight automated manufacturing, electrical, and mechanical majors for the project, and assigned the faculty advisor for the team. The student team visited with the industrial contact, gave the scope presentation, and developed the project proposal during the fall semester. The student team was constantly contacting vendors, meeting with their faculty advisor, and communicating with their industrial representative. Initial orders for materials were placed at the end of the fall semester. During the spring semester the team completed ordering materials, had several semi-formal design reviews with faculty, gave a formal update presentation, maintained a real dollar budget of about $30,000, and physically implemented the complete system. At the end of the project, the team's design met an acceptance criteria of successfully testing 500 parking brakes within a specified time period. The team provided a complete formal report on the project. The final formal presentation was given to a general audience consisting of university faculty and staff, industrial representatives, and the students' family and friends. The company then shipped the unit from the university to their industrial site for use in their assembly process.

Conclusion

Industrial-based design projects are a true win-win partnership for the university and the company. Where a proper project culture and process exists, the students receive invaluable practical experience and the company receives a good return for their participation. The students gain confidence and experience from working on a multidisciplinary team, interfacing with industrial and vendor representatives, managing a real project with a real dollar budget, and achieving success by completing a complex project. The industrial need and expected project outcomes drive the entire process with academics providing sound guidelines, knowledge, and student resources. This project experience is by no means easy to supervise, manage, or teach. The key element to the success of these types of projects is a team of faculty representing several disciplines who are dedicated to working together to provide their students with a high quality senior design project experience.

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