Multidisciplinary Engineering Senior Design at RIT

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Abstract

The Kate Gleason College of Engineering (KGCOE) at the Rochester Institute of Technology (RIT) has implemented a college-wide initiative to emphasize multidisciplinary design in the senior capstone experience. The mission of this three-quarter sequence is to develop engineers who have an end-to-end life cycle prospective of product realization. Problem solving, teamwork, market-oriented product development, and technical communication are key experiential components of the program. Supplemental topics in innovation, entrepreneurship, and contemporary issues in product development, are fostered through lectures and workshops.

The capstone program is coordinated by a team of faculty representatives from each participating department. A standard set of assessment tools is employed by the coordinators, faculty team mentors, project sponsors and external reviewers.

The design of a state-of-the-art 8,500 sq.ft., multi-disciplinary design workshop is underway. It will provide team work spaces as they develop and analyze concepts, and support for assembly and testing. This facility is made possible by recent gifts from local foundations and industries. At steady state, approximately 400 students will work concurrently on approximately 60 projects. This paper discusses the educational objectives, structure, and management of this multidisciplinary capstone program.

Introduction

During the 2002-2003 academic year, the Kate Gleason College of Engineering (KGCOE) took another step to strengthen multidisciplinary design in the curricula. The extant capstone experiences in the Electrical, Mechanical and Industrial Engineering departments have been consolidated into a three quarter design program. Now in the second year, this pilot program involves 200 students, from these departments working on 28 projects. When fully deployed, approximately 400 students from the College's five academic disciplines (Mechanical Engineering, Electrical Engineering, Industrial and Systems Engineering, Computer Engineering, and Microelectronics Engineering) will work concurrently on approximately 60 projects each year. This initiative is managed by a team of faculty advocates from the participating departments, and is supported by 20 additional faculty team mentors. The initiative is funded by a grant from the Gleason Foundation but will become self-sustaining as it matures.

Traditionally, each department in the College conducted its own capstone experience within the confines of the discipline. Multidisciplinary design projects were undertaken in the past, but only a few each year were possible due to scheduling problems, faculty availability, and limited funds.

The deployment of multidisciplinary design throughout the College curricula is a strategic objective. The College's undergraduate honors program employs the multidisciplinary design paradigm. A multidisciplinary capstone concludes both the Masters in Product Development (MPD) and Masters in Manufacturing Leadership (MML) programs offered to experienced managers. The nascent Microsystems Ph.D. program was designed to have strong product realization and systems engineering components.

Program Structure

Projects may be proposed by industrial sponsors, faculty members engaged in research, or arise from the Institute's collaborative activities. Projects closely allied with a faculty member's research interests are especially attractive because they yield a substantial return on faculty time invested. The project proposal processes begins with a sponsor's statement outlining a pro forma scope, deliverables, resources available to the student team, and engineering skills required to successfully complete the project. Proposals are then examined by the faculty coordinator team to insure feasibility. Modifications may be made to fit both the sponsor's requirements and the College's educational objectives.

The program consists of three blocks spanning the fall, winter and spring quarters.

In the first block, a Design Project Management (DPM) course for prospective team leaders is offered. This course has two top-level objectives: (1) to build skills in leadership, project planning, problem definition, concept development, concept selection, and performance validation; and (2) to lay the foundation of the project assigned to them in preparation for a team of 5-7 students who will undertake the project in the winter quarter. The course meets twice per week for two hours. In the first hour, students are introduced to the multiple facets of product and process design. The second hour is a workshop in which students apply these concepts, and attendant tools, to their project. By the end of the DPM course, team leaders have produced a preliminary needs assessment and project plan that will guide the team through 22 weeks of work. Most students completing the DPM course go on to become team leaders. However, some elect to become chief engineer instead. Chief engineers focus on the more technical aspects of problem definition, concept development, concept selection, and performance validation, while team leaders focus on project management.

In the DPM course, and throughout the program, a multi-facetted paradigm is used to teach basic concepts in product and process development. These are (1) Needs Assessment, (2) Concept Development, (3) Feasibility Assessment, (4) Specifications and Objectives, (5) Analysis & Synthesis, (6) Preliminary Design, (7) Engineering Models & Prototyping, (8) Detailed Design & DFx, (9) Production Planning, (10) Pilot Production, (11) Transition to Commercial Production, and (12) Product Stewardship. Movement through these facets is not serial. Rather, projects progress in an iterative fashion as appropriate. By the end of the second block, all teams are expected to complete facets 1-6. Some teams go on to facets 7-9.

Facet 1, Needs Assessment, focuses on understanding the top level project requirements. It typically consists of a mission statement, a product/project synopsis, a scope statement, the delineation of stakeholders, the key business goals, a financial analysis, a definition of the secondary applications, key marketing attributes, and innovation opportunities.

Background research and processes for generating design concepts are the focus of Facet 2. Students learn how to search for patents, academic literature, and professional literature that can help them understand potential design approaches. Creative techniques, such as brainstorming, synectics, group drawing, empathy, and morphological analysis, assist in concept development.

Project feasibility is the focus of Facet 3, consisting of four major aspects: resource feasibility, economic feasibility, schedule feasibility, and technical feasibility. Students learn structured methods, such as Pugh Technique and weighted attribute methods, to evaluate the relative risk among alternatives.

Facet 4 deals with the development of top level requirements, performance requirements, and detailed design specifications. Problem analysis, synthesis of multiple concepts, and systems integration are the focus of Facet 5. Facet 6, addresses the creation of preliminary drawing packages, assembly and component drawings, bills of material, and supplier selection.

Facet 7 introduces various methods of demonstrating proof of concept, such as simulation, breadboard models, and prototypes. In Facet 8, students learn the need to consider safety, manufacturability, maintenance, assembly, disassembly, recycling, and quality while designing their system. Facet 9 introduces process flow sheets, work cell design, fixture design, automation, and other concepts in production planning.

Facet 10 focuses on major issues in pilot production, such as process validation and operator training. The transition from prototype to pilot production to commercial production is the domain of Facet 11. Topics include standardization, interchangeability, mass customization, and capitalization. Facet 12 concludes the product life cycle. Concepts in product maintenance, product recall, after-sale support, remanufacturing, reuse, and resource recovery are introduced.

Senior Design I, occurring in the winter quarter, is the second block of the program. Students bid for, and are then assigned to projects after an intense recruiting period. Within the first two days, team leaders conduct a 2½ hour poster session that introduces classmates to the portfolio of available projects. On the first day of class, team leaders give a 2 ½ minute project overview that is followed by a second 2 hour poster session. By the end of the first week, students register their top three project choices via a web-based survey form while team leaders submit their team member requests to the faculty coordinators. This information, together with the skills mix required by the projects, and constraints on the number of available students, is used to by the faculty coordinators to assign students to teams. Assignments are distributed to the students before the beginning of the second week of class begins so that teams can begin work on the project. Their first task is to meet with the project sponsor and faculty mentor, then revisit the preliminary needs assessment developed by the team leader in the DPM course.

Throughout the quarter, the entire class is introduced to the 12-facet paradigm outlined above, and the teams begin to apply the concepts to their project in a workshop forum. Teams generate preliminary concepts and evaluate them against performance and feasibility criteria, then go on to develop a preliminary design. Throughout this block, teams meet regularly with their sponsor and team mentor. At the conclusion, their work is formally reviewed by a panel of faculty, sponsors, and industrial representatives, in a forum referred to as the Preliminary Design Review (PDR). Evaluation of student performance also includes class participation, contribution to the project, and overall the team achievement as documented in a Technical Data Package (TDP).

After the PDR, teams may initiate the acquisition of prototype components by writing purchase request. Once approved by the faculty mentor, these requests are converted to purchase orders by the department's administrative staff. The goal is to acquire the components over the two-week break period between the winter and spring quarters so that teams can build prototypes as soon as they return.

The third block is completed in the spring quarter. Teams concentrate on remaining design details, design revisions, prototype construction, and testing. They continue to meet regularly with the project sponsor and faculty mentor throughout this period. At the conclusion of the block, teams submit a 5-page technical conference paper, complete their project web page, submit an updated Technical Data Package, and demonstrate their prototype. The projects are again formally reviewed by a panel of faculty, sponsors, and industrial representatives. Faculty coordinators draw on these evaluation instruments to arrive at both team and individual student grades.

How the Capstone Experience Develops Engineering Competencies

The realization of complex and technologically advanced systems require the skills of a multidisciplinary team. This capstone responds to this need. While some projects may be centered in one of the academic disciplines, all projects require the skills of at least one other engineering discipline. "Archeological Investigation Technology," "Automated Medication Dispenser," "Lightweight High Economy Vehicle," "Increased Quantity per Hour Hydraulic Motor Manufacturing," and "Fuel Injector Droplet Sensor," are titles of some of the current projects.[1]

Otto[2] describes the requisite skills of highly effective multidisciplinary teams as follows:

Multidisciplinary Teamwork: Students must learn to work effectively with people that do not necessarily think or talk like themselves. They must learn to understand and appreciate the value the skills that each team member provide and then employ these various skills in the most optimum way within a cohesive plan to produce the most optimum product. The challenges of working within a multidisciplinary team environment include, team problem-solving, project management, and team communication.

Market-Oriented Product Development Focus: Students must learn to identify and then transform customer problems, needs, market opportunities, or requirements into product attributes and specifications. There must be a shift in student perspective from, "we are doing this project because it was assigned to us towards, "we have identified customer needs through consultation with our client and we have developed performance specifications based on these needs."

Technical Communication: Students must be able to share ideas within the team as well as clearly articulate, justify and defend ideas with the team, external customers and reviewers.

Multidisciplinary Engineering and Realistic Design Constraints: Students must incorporate engineering standards and design constraints that impact engineering solutions across all disciplines. Thus, students gain an appreciation for how/why colleagues may be constrained in their design solutions. For example, an industrial engineer may be questioning the cost or manufacturability or a specified material while the mechanical engineer is constrained by strength characteristics.

The competencies described above have influenced the capstone objectives which are directly linked to the ABET program outcomes of the participating departments. Following Bloom's Taxonomy,[3] these are:

Level 1: Knowledge -

- Learn about various Engineering Design Methods and Processes;
- Understand the influence of Team Dynamics and interpersonal interaction in a working environment;
- Have a basic understanding of the concepts and tools of engineering design project management; and
- Understand the various forms of intellectual property, various forms of protection available for such intellectual property and the roles and responsibilities of the engineering relating thereto.

Level 2: Comprehension

- Demonstrate comprehension not only of knowledge learned in this course, but also demonstrate comprehension of knowledge gained in previous courses and during past co-op work experiences.

Level 3: Application

- Apply a formal Engineering Design Methods to the solution of a multi-disciplinary design problem.
- Have experience functioning as a (*mechanical, electrical, or industrial)* engineer within an engineering design and development group.
- Complete a ``real-life" design task - transform a client's needs into a tangible, tractable project definition, and see the project through to completion.

- Understand and use a formal engineering design method, with emphasis on building concurrent engineering procedures into the basic design method.
- Be proficient in the preparation of Oral and Written Reports and Technical Data Packages.

Level 4: Analysis

- Become proficient in preparing and reviewing formal technical data packages related to an engineering design.
- Apply the broad range of technical tools and engineering sciences learned during the previous formal education.

Level 5: Synthesis

- Be ready to begin a career as an engineer.
- Synthesize the learning achieved from not only the formal classroom experiences, but also co-op work experiences, to form a solid foundation for subsequent professional development.
- Be able to function in a multi-disciplinary environment.
- Understand the importance of life-long education.

Conclusion

The Rochester Institute of Technology has a life-long history of responding to the needs of the industrial community. In this case, the Kate Gleason College of Engineering has undertaken the task of producing engineers capable of working effectively on multidisciplinary teams. To this end, the KGCOE has defined the strategic objective of becoming the national leader in multidisciplinary engineering design, project management, and product innovation. The Multidisciplinary Engineering Design Program is an important step toward this objective. There are several other initiatives as well, for example the Freshman Honors Program, the Master's in Product Development Program, the Masters in Manufacturing Leadership, and the Microsystems Engineering Ph.D. program. This program will continue to grow and improve with the support of a very enthusiastic faculty, university administration, and industrial sponsors.

References

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Biographies

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