Enhancing the Capstone Design Experience in An Undergraduate Engineering Program

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Abstract:

Senior engineering students in the School of Engineering, Computing and Construction Management at Roger Williams University are required to take a two-semester senior capstone design-course sequence. Not unlike the experience offered in many engineering programs, the capstone design experience is meant to be an integrative event during which students apply the engineering science and design principles learned during their previous studies to an actual project. At Roger Williams, the course has been undergoing a transition to a client-based format in which all of the student design projects are undertaken for “outside” clients.

This fall a major initiative was undertaken that incorporated into the course a unique block of instruction on the Malcolm Baldrige Criteria for Performance Excellence. The Baldrige performance excellence criteria are the framework that any organization can use to improve overall performance. This instructional unit was introduced to enhance the students’ awareness of the need for continuous improvement within a highly competitive world marketplace and, by extension, to improve the client base senior design project products.

This paper presents the development and implementation of this unique integration with a preliminary assessment of the results.

Introduction:

During the summer of 2003, discussions were held between the School of Engineering, Computing and Construction Management (SECCM) at Roger Williams University and the Rhode Island Center for Performance Excellence (RICPE) regarding the possibility of engineering students working with regional companies that were involved with the Baldrige National Quality Program. The RICPE had previously recruited students from other regional institutions to participate in this program but, heretofore, these students had been undergraduate or graduate students from their respective institutions’ business schools. The RICPE had identified a need for students with a technological background to participate with those companies with a significant technological or engineering focus to their business.

This opportunity for greater collaboration with the local business community was very timely. Over the past two years, the administration and faculty of the SECCM had been working to transition the senior engineering capstone design course to a “client-based” format. Under a “client-based” scenario, all of the projects offered to student teams for their capstone projects
would be generated by entities outside of the academic environment. The value of “client-based”
design is that the students are “working” for clients (industry, private and governmental
institutions) that are future employers on “real world” issues. “Client-based” design promotes the
natural maturation of engineering students and helps prepare them for transition to the
marketplace.

The proposed collaboration between RICPE and SECCM had several objectives.

- Introduce senior engineering students to the Baldrige National Quality Program and the
  Baldrige Criteria for Performance Excellence.
- Provide regional companies with a technological/engineering focus with a potential
  resource to facilitate their efforts to improve their processes and performance and to
  enhance their competitiveness in the global marketplace.
- Provide senior engineering students with a source of meaningful, sponsored “client-
  based” capstone design projects.
- Increase the outreach and collaboration between the SECCM and regional business
  community.

Description of the SECCM Senior Capstone Design Course Sequence:

The overarching goal of the senior capstone design experience at Roger Williams University is to
produce engineering graduates who have the professional experience, self confidence, personal
responsibility and practical knowledge necessary to become immediately productive in today’s
highly competitive, team-oriented and interdisciplinary workplace. The senior design experience
consists of a two-semester course sequence, ENGR 490 and ENGR 492 (Engineering Design I
and II).

The first semester (ENGR 490, Engineering Design I) has typically consisted of a mixture of
design-related classroom instruction and design project selection and initial preparation.
Classroom topics have traditionally included instruction on problem formulation, identification
of requirements, development of alternatives, and so forth. Recently, we incorporated the QFD
(Quality Function Deployment) process into the course to provide the students with a
methodology for design.

In addition to this classroom instruction, students are presented early in the semester with a list
of projects for their design projects. The project list tends to be very diverse. Each project has a
volunteer faculty mentor (with disciplinary expertise in the project domain) who has agreed to
work with the student team as a technical advisor. Team formation/ project selection is
accomplished through a combination of student self-selection and instructor oversight. It is
anticipated that by the end of the first semester, that the project teams will have completed their
initial design and project preparation activities and be prepared for detailed design and
fabrication activities during the second semester.

During the second semester (ENGR 492), class attendances are minimal while student team
effort is focused on the actual work required to complete the design project under the guidance of
their technical faculty advisor. Frequent meetings and progress review sessions are conducted to
facilitate the design effort and to assist the teams in staying on track. While the final deliverable product varies from project to project, most projects are selected so that the design effort results in a working prototype. Final presentations are made to faculty and clients and the evaluation of a team’s design work includes the client’s satisfaction with the delivered product.

Description of Baldrige National Quality Program:

Malcolm Baldrige was Secretary of Commerce from 1981 until his death in a rodeo accident in July 1987. Baldrige was a proponent of quality management as a key to this country’s prosperity and long-term strength.

The Baldrige Award is given by the President of the United States to businesses – manufacturing and service, large and small, - and to education and health care organizations that apply and are judged to be outstanding in seven areas: leadership, strategic planning, customer and market focus, information, analysis and knowledge management, human resource focus, process management, and business results.

Congress established the award program in 1987 to recognize U.S. organizations for their achievements in quality and performance and to raise awareness about the importance of quality and performance excellence as a competitive edge. A report, Building on Baldrige: American Quality for the 21st Century, by the private Council on Competitiveness, said, “More than any other program, the Baldrige Quality Award is responsible for making quality a national priority and disseminating best practices across the United States”

For 16 years, the Baldrige Performance Excellence Criteria have been used by thousands of U.S. organizations to stay abreast of ever-increasing competition and to improve performance. For today’s business environment, the Criteria help organizations respond to current challenges: openness and transparency in governance and ethics; the need to create value for customers and the business; and the challenges of rapid innovation and capitalizing on their knowledge assets. Whether a business is small or large, is involved in service or manufacturing, or has one office or multiple sites across the globe, the Criteria provide a valuable framework that helps a business to plan in an uncertain environment. The Criteria helps an organization to align resources and approaches, such as ISO 9000, Lean Enterprise, Balanced Scorecard, and Six Sigma; improve communication, productivity, and effectiveness; and achieve strategic goals.

The Baldrige performance excellence criteria are that framework used to improve overall performance. Seven categories make up the award criteria:

- Leadership – Examines how an organization’s senior leaders address values, directions and performance expectations, as well as a focus on customers and other stakeholders, empowerment, innovation, and learning. Also examines an organization’s governance and how the organization addresses its public and community responsibilities.

- Strategic Planning – Examines how an organization develops strategic objectives and action plans. Also examines how an organization’s chosen strategic objectives and action plans are deployed and how progress is measured.
Customer and Market Focus – Examines how an organization determines requirements, expectations, and preferences of customers and markets. Also examines how an organization builds relationships with customers and determines the key factors that lead to customer acquisition, satisfaction, loyalty and retention, and to business expansion.

Measurement, Analysis, and Knowledge Management – Examines how an organization selects, gathers, analyzes, manages, and improves its data, information and knowledge assets.

Human Resource Focus – Examines how an organization’s work systems and employee learning and motivation enable employees to develop and utilize their full potential in alignment with an organization’s overall objectives and action plans. Also examines an organization’s efforts to build and maintain a work environment and employee support climate conducive to performance excellence and to personal and organizational growth.

Process Management – Examines the key aspects of an organization’s process management, including key product, service, and business processes for creating customer and organizational value and key support processes. This category encompasses all key processes and all work units.

Business Results – Examines an organization’s performance and improvement in key business areas – customer satisfaction, product and service performance, financial and marketplace performance, human resources results, operational performance, and governance and social responsibility. Also examines performance levels to those of competitors.

For many organizations, using the criteria results in better employee relations, higher productivity, greater customer satisfaction, increased market share, and improved profitability. According to a report by the Conference Board, a business membership organization, “A majority of large U.S. firms have used the criteria of the Malcolm Baldrige National Quality Award for self-improvement, and the evidence suggests a long-term link between use of the Baldrige criteria and improved business performance.”

Integration of the Baldrige Criteria Performance Excellence into the Capstone Design Experience:

Initial discussions between the RICPE and the SECCM focused on whether or not integration of the Baldrige National Quality Program into the senior capstone design curriculum was appropriate and would enhance the design experience. Two factors tilted the decision in favor of integration. First, the dynamic and increasingly global and competitive nature of the marketplace is changing the world in which are graduates are about to enter. The Baldrige program provided them with an appreciation for the types of issues that are rarely examined during the undergraduate engineering experience. Second, our engineering students, not unlike engineering students at most institutions, tend to see the world in terms of engineering analyses, often detached from their economic and business consequences. We felt that exposure to the
“business” side of the engineering profession would be an extremely valuable lesson to their educational process.

As part of the assessment process, the following course objectives were developed with regards to the Baldrige program integration:

1) Identify the various perspectives for defining quality and introduce the Criteria for Performance Excellence to engineering students as an integrative framework for guiding the continuous improvement process and the role it plays in business.

2) Develop a working knowledge of the tools (Seven Step Problem Solving Process, etc.) used to plan and implement continuous improvement efforts and the challenges inherent in successfully implementing these tools.

3) Develop an understanding of the importance of process design as the basis of product/service quality.

4) Discuss the role that continuous improvement plays in an organization’s search for sustainable competitive advantage.

After considerable discussion between the RICPE and the SECCM it was decided that integration of the Baldrige criteria into the design course sequence would be accomplished through a 14-lesson program spread throughout the fall semester. This decision required considerable dedication of resources by both organizations. The instruction would be provided by the RICPE and would be patterned after the existing “Journey to Performance Excellence” formal program normally reserved for corporate executives and senior managers.

The Director of the RICPE presented the classroom instruction to the students during their normal classroom meetings. Typically, Baldrige instruction was limited to one presentation per week to permit the presentation of the normal design-related instruction that would occur during the fall semester. The course content consisted of the following lessons:

- Overview
- Problem Solving I
- Problem Solving II
- Team Work I
- Team Work II
- Leadership
- Strategic Planning
- Customer & Market Focus I
- Customer & Market Focus II
- Measurement, Analysis and Knowledge Management
- Human Resources Focus I
- Human Resources Focus II
- Process Management
- Business Results/Wrap Up

It was recognized that some of the topics included in the presentation were less relevant to the immediate needs of the students enrolled in the senior engineering design experience than others. For example, the problem solving, teamwork, customer & market focus, and measurement analysis and knowledge management lessons are directly relevant to the design process. Lessons on leadership, strategic planning, and human resources are less so. It was decided that presenting
the entire program, as it has been presented to corporate managers across the nation, provided the students not only with excellent insight into the global marketplace, but with an extremely valuable and nationally recognizable program that would enhance their employment opportunities upon graduation.

In order to accomplish this integration, the course instructor agreed to dedicate half of the semester to the program. This required a revision of the normal material presentation and a loss of flexibility and time that had previously been devoted to design-related lessons and project development activities.

Assessment:

Given the fact that the course is still ongoing, a thorough assessment of the efficacy of this initiative is not possible. A survey will be administered to all students at the end of the year (and upon completion of their capstone projects) to assess their opinions regarding the Baldrige instruction and its impact on their capstone design product. The results of this assessment will be presented at the upcoming conference and will be included in a planned future publication.

Preliminary observations were obtained, however, from a course survey conducted after completion of the instruction and prior to the end of the fall semester. From the student perspective, reaction to the integration of the Baldrige instruction was mixed. Students praised the exposure to the business culture and the “real world” and commented that they felt that they now had “a feeling of what is going on outside of school.” They also commented that the Baldrige instruction provided them with a “benchmark” that would be useful in the future. They acknowledged that the instruction made them better rounded and more valuable as future employees and co-workers. They also acknowledged an increased awareness of the global business environment that would be valuable after graduation. There were, however, a significant number of student comments that suggested that the Baldrige instruction “took away” time from their engineering design instruction. Others commented that the instruction was too condensed and intense.

The Baldrige instructor noted that the engineering students would have benefited more had they had a broader business background. (Engineering students are required to take one business course and one economics course as part of their program.) He noted that the engineering students, in general, failed to have a fully developed appreciation that the engineering profession is, more often than not, practiced in the context of a business enterprise.

This last observation is noteworthy. As a faculty, we have observed that our students, as well prepared as they might be to practice engineering, are often dismissive of the practical, “business” aspects of the engineering profession. It is our observation that this tendency is not limited to engineering graduates of our institution alone.

Bibliography:


Biographical Information:

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