A Practice-Based Senior Design Experience

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Abstract

This paper presents an overview of a practice-based capstone design experience. Information about past industrial sponsorship of course projects, course structure and requirements, professional practice integration, and assessment results is provided. A primary objective of the experience is to transition students from their classroom roles into their professional roles as practicing engineers. Details of how the course facilitates this transition are discussed. Finally, results of an alumni assessment survey are presented. The goal of the practice-based senior design experience at Baylor University is to produce engineering graduates who have the self-confidence and practical knowledge necessary to become immediately productive in today's project-oriented workplace. Interpretation of these assessment results supports the conclusion that this goal has been met.

I. Introduction

Engineering design is integrated throughout the curriculum at Baylor University, and meaningful design work is required of students in many courses beginning with the introductory freshman course and progressing through the senior electives and laboratories. However, EGR 4390 *Engineering Design II* is the capstone design course that provides the major design experience at Baylor. Differing forms of the capstone design experience have been presented by other authors.[1-2]

The core course at Baylor emphasizes the interdisciplinary nature of engineering design and is team-taught by at least one mechanical engineering faculty member and one electrical/computer engineering faculty member. The objective of the course is to facilitate the transition from academia to professional engineering practice and to integrate the accumulated background of the engineering student. The project to be designed, built, and tested, as the central requirement of this course is typically an integrated electromechanical system with computer control, necessarily drawing from earlier courses in engineering, business, and the liberal arts. That this course is truly a "capstone experience" is evidenced by the course prerequisite of predicted graduation before the next regular semester.

In recent years, external funding from industrial clients has provided Baylor engineering students with "real-world" capstone design experiences.[3] Listed below are the externally funded senior design projects for the last several years:

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- $10,000 Cygnal Integrated Products, spring 2002, *Cygnal Educational Development System*
- $10,000 Raytheon, spring 2002, *Bench-Top Dynamic Hydraulic Controller*
- $10,000 Raytheon, fall 2001, *Vibration Isolator Test System*
- $10,000 Trinity Industries, spring 2001, *Self-Powered Data Acquisition and Transmission System*
- $10,000 Raytheon, spring 2001, *Empirical Relationships for Non-Standard Orifices*
- $10,000 Raytheon, fall 2000, *Airflow Balancing Test System*
- $10,000 Raytheon, spring 2000, *Sound Intensity Level Measurement System*
- $10,000 Raytheon, fall 1999, *Aircraft Fuselage Thermal Conductance Test Machine*
- $10,000 Raytheon, spring 1999, *Resonant-Beam Damping Material Test Chamber*
- $10,000 Raytheon, fall 1998, *Acoustic Impedance Tube*
- $10,000 Raytheon, spring 1998, *Photogrammetric Parts Inspection Station*
- $10,000 Raytheon, fall 1997, *Center of Gravity Test Machine*
- $10,000 Elk Corporation, spring 1997, *Asphalt Shingle Sheet Break Preventor*
- $5,000 ASHRAE, fall 1996, *Instrumentation of Water Source Heat Pumps for Engineering Laboratory Experiments*
- $12,000 Alamo Steel Company, spring 1995, *Computer Numerically Controlled (CNC) X-Y Coordinate Table*

Thus, the senior design course at Baylor University provides, in effect, an internship experience for the students in which their practice of engineering must conform to generally accepted professional standards as much as practical within the confines of a fifteen-week semester. The goal is to produce engineering graduates who have the self-confidence and practical knowledge necessary to become immediately productive in today's project-oriented workplace.

II. Course Structure

In EGR 4390, students work together as a single interdisciplinary design team with an organizational and management structure that is implemented by the students. The team size has varied from a low of 6 students in the fall of 1998 to a high of 21 students in the spring of 1999. The average team size for the projects listed above is 12 with a nearly even split between mechanical engineering students and electrical/computer engineering students. In response to enrollment growth, multiple sections of EGR 4390 have been offered in recent spring semesters to maintain the small team size. A room in the engineering building is reserved exclusively as the senior design team's office. Members of the senior design class have card access to this room; all other students are denied access. It is furnished with conference tables and chairs, networked computer workstations with DAQ cards, a large format plotter, a vendor library, research and development benches with lab instruments, a telephone with long-distance privileges, and a white board.

Typically, the semester begins with the design team being furnished a statement of need prepared by the client, followed by an on-site project briefing and a tour of the client's facility with emphasis on those areas affected by the client's need. The design team must then specify, design, build, and test a prototype device in response to that need. Software design includes a computer-assisted data acquisition and control system. Hardware design includes an operating device along with necessary support structures, mounting fixtures, mechanical and electrical subsystems, utilities, and instrumentation and controls required of the device. Deliverables include student-developed software modules, an owner's manual, an operator's manual, and a final engineering report to include test results and a complete as-built drawing set of the device.

The end-of-semester tradition of hanging a "hall-of-fame" drawing of the system on a wall in the main hall of the engineering building was begun in 1992. This has become a source of *esprit de corps* within the department of engineering by encouraging the seniors to leave behind a permanent legacy of their senior design work. An example hall-of-fame drawing from the fall 2001 semester is shown in Figure 1 below.

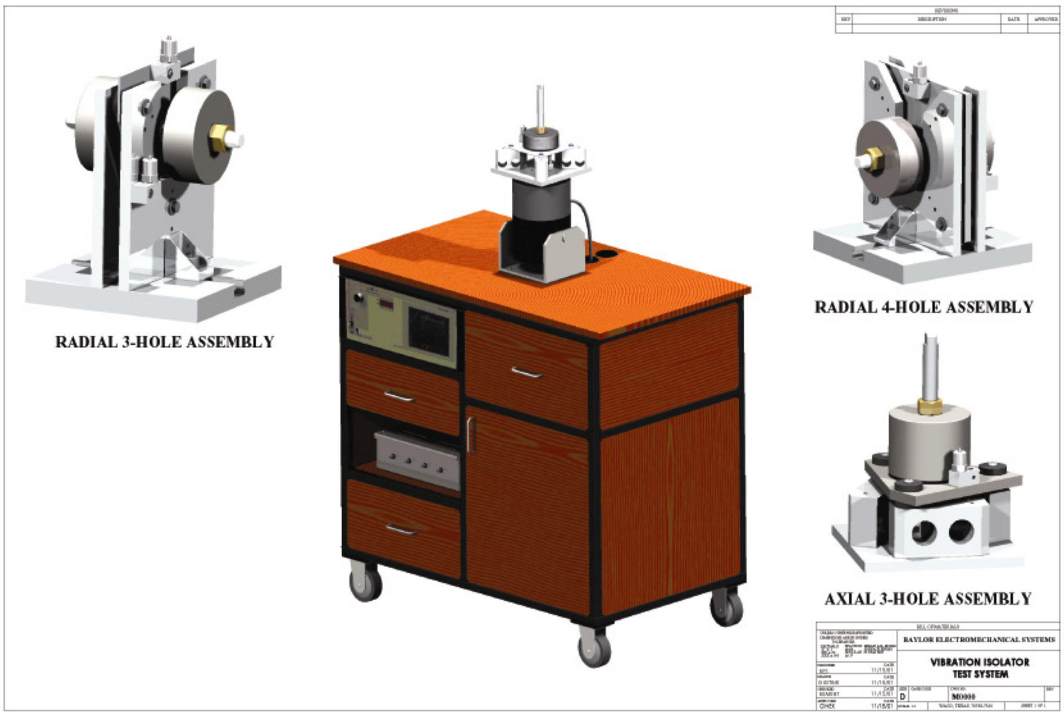

Figure 1 – Typical Hall-of-Fame Drawing

In addition, the department of engineering maintains a web page documenting the recent history of the senior design projects, including specific project descriptions and samples of student work. This web page also provides access to current course materials, including the syllabus, calendar, evaluation forms, and the notebook specification. It may be viewed at http://ecswww.baylor.edu/faculty/doty/EGR4390/EGR4390.html.

III. Course Requirements

The senior design class is scheduled as two hours of lecture and a three hours of laboratory per week. The two lecture hours are used as staff meetings, with the faculty and the students sharing in the delivery of information. A weekly design milestone is the focus of these staff meetings. The three-hour laboratory concludes the week's activities with an activity related to that week's design milestone. Major milestones require formal design submittals as described below.

Design Milestones
The weekly design milestones for this course are: Statement of Need, Project Definition, Concepts Evaluation, Conceptual Design Report, Subsystems Review, Preliminary Design Review, Final Construction Documents, Final Design Presentation, Construction, Subsystems Test, System Integration, Compliance Test, Report of results, and Project Overview. One or more practicing engineers representing the client are usually present at the major milestone meetings and provide valuable real-world insight and constructive criticism.

Design Submittals
The design team must fully document the project by use of computer-aided engineering calculations and drawings. The BES drafting manual prescribes the drafting practices used in preparation and revision of engineering drawings for the design and construction of electromechanical systems. The BES drafting manual is distributed electronically online at: http://ecswww.baylor.edu/faculty/doty/EGR4322/BESDraftingManual.pdf.

Significant use of a computer by every member of the design team is required. Construction drawings are computer generated and plotted on D-size paper. Written submittals are word-processed, laser printed in color, and professionally bound. Two videotaped formal oral presentations are required with professional-quality computer-generated visual aids. A brief description of the major design submittals follows.

Conceptual Design Report: This written document must include introductory project information including a description of the client, an organizational chart for the design company including mission statements by department and identifiable milestones, documentation of the proposed hardware and software, a proposed procedure for verifying system performance, and a proposed standard operating procedure.

Preliminary Design Review: A complete set of preliminary working drawings is submitted for review by the faculty, the client, the machinist, and the electronics systems manager.

Final Construction Documents: The final design documents consisting of a complete set of construction drawings and technical specifications.

Final Design Presentation: The first half of the semester finishes with a videotaped formal oral presentation in the afternoon that is open to the public and is attended by members of the engineering faculty and student body, as well as representatives of the client. This is an overview of the technical aspects of the design directed toward a technically trained audience, after which questions are directed to members of the design team.

Report of Results: An informal oral overview of the compliance test results and the final deliverables are due at this time. The deliverables include an operating device, supporting software modules, an owner's manual, an operator's manual, and a final engineering report to include test results and a complete as-built drawing set of the device.

Executive Overview: The semester culminates in a videotaped formal oral presentation in the evening that is open to the public and is attended by many members of the engineering faculty and student body, as well as representatives of the client, and friends and relatives of the senior engineering students. This is an overview of the design project directed toward a non-technical audience, after which refreshments are served and demonstrations of the finished device are conducted. Examples of the senior design work are displayed at the reception and student led tours of the engineering building are offered.

IV. Professional Practice

The design team, under the direction of its project managers, must implement realistic design milestones, deliver high-quality design submittals, practice competent project management and budget tracking, maintain professional interaction between the design team and the client, maintain professional interaction between the design team and the vendors, gain experience with relevant manufacturing processes, utilize modern computer-aided design tools, and implement a professional approach to the evaluation of engineering work. Some of these professional activities are described further in the following paragraphs.

Vendor Interaction
Students are given access to vendor catalogs, and the Internet, as well as long-distance telephone and FAX privileges. They are required to contact vendors, secure design information, select components, obtain budget prices, write purchase requisitions, and expedite delivery of parts and materials.

Computer-Aided Design
As a minimum each student is expected to be proficient with the Microsoft Office Suite consisting of Word, Excel, and PowerPoint. Mechanical drawings are produced using professional solid-modeling software and a user-interface is produced using LabVIEW. Other major computer-aided design tools are also used as required by the design process. Typical examples are PSpice, TurboCAD, MATLAB, and MathCAD.

Design Evaluation
The final course grade depends not only on individual performance but also on the overall performance of the design team. Half of the course grade is derived from an assessment of individual performance and the other half from the team performance, as outlined below. Various aspects of performance that are evaluated subjectively include technical knowledge, engineering judgment, contribution to project effort, contribution to project quality, leadership contribution, performance under stress, oral communication skills, written communication skills, professional ethics, and human relations. Individual work that is evaluated consists of oral presentations, individual contributions to the team project, and class participation. Each presenter is responsible for the quality of visual aids used during their part of the presentation.

Individual contributions to the team project are documented in individual design notebooks in accordance with *Engineering 4390-Engineering Design Notebook Specification.* The first entry in the design notebook is a narrative statement of individual work outlining that person's contributions to the project. These contributions are supported by frequent reference to other documents included in the notebook. The quality of the contribution, as well as the magnitude of the effort, is judged by the faculty in evaluating the individual notebook. Class participation by the student, as judged by the perceptions of the faculty, affects this grade component.

The team performance grade is determined from the quality of the team submittals; including, but not necessarily limited to, the conceptual design report, the final construction documents, the final design presentation, the final project deliverables, and the executive overview presentation. Peer evaluation is used to modify the team performance grade for each student.

V. Assessment

As part of our ongoing program assessment process, alumni are surveyed to determine the impact of their academic engineering experience on their professional careers. Alumni who have graduated from two to six years ago are asked to rate Baylor's role in meeting twelve different engineering program objectives based on their cumulative job experience. Of the twelve program objectives, eight are stated objectives of senior design.

1. An ability to apply knowledge of mathematics, science, and engineering.
2. An ability to design and conduct experiments, as well as analyze and interpret data.
3. An ability to design a system, component, or process to meet desired needs.
4. An ability to function on multi-disciplinary teams.
5. An ability to identify, formulate, and solve engineering problems.
6. An understanding of professional and ethical responsibility.
7. An ability to communicate effectively.
8. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

In the alumni survey conducted in the spring of 2000, responses were obtained from 58 alumni. This was the first alumni survey conducted resulting from the EC2000 accreditation process. The 58 responses represented over 25% of alumni in the two to six year post-baccalaureate period. Possible alumni responses indicating Baylor's role in meeting the program objectives were above adequate, adequate, and below adequate. Table I summarizes the percentage of responses in each category – the eight program objective numbers are keyed to the listing shown above.

Table I
Percentage of alumni assessing Baylor's role in meeting program objectives

Program Objective Number	**Above Adequate (%)**	**Adequate (%)**	**Below Adequate (%)**
1	57	43	0
2	41	57	2
3	45	55	0
4	74	26	0
5	43	57	0
6	50	50	0
7	53	45	2
8	43	53	3

Among the eight senior design objectives, all alumni respondents indicated that Baylor's role in meeting those objectives was either adequate or above adequate based on their job experience since graduation. Above adequate responses among those eight program objectives ranged from 23 of 58 to 43 of 58. In the narrative comments associated with above adequate responses, 24 respondents explicitly listed senior design as directly contributing to those program objectives.

The most above adequate responses were with regard to an ability to function on multi-disciplinary teams (43 of 58). Senior design plays a key role in meeting this program objective because it combines the skills of computer, electrical, and mechanical engineering students.

The survey also asks alumni to list the most and least useful classes they had in their undergraduate curriculum. Of the 58 respondents, 38 stated that senior design was one of the most useful classes in their curriculum. None of the respondents indicated that senior design was one of the least useful classes in their curriculum.

Based on alumni comments, certain features of the senior design experience appear to have a positive impact on their professional careers. The feature set includes close industry interaction on senior design projects; being treated as engineers (not students) by the senior design faculty; the opportunity to create professional engineering reports and presentations that are delivered to a real industrial client; and an interdisciplinary design environment comprised of computer, electrical, and mechanical engineering students and faculty.

The goal of the practice-based senior design experience at Baylor University is to produce engineering graduates who have the self-confidence and practical knowledge necessary to become immediately productive in today's project-oriented workplace. Interpretation of these assessment results supports the conclusion that this goal has been met.

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