2007: EVOLUTION OF A CAPSTONE DESIGN PROGRAM: CHANGES IN FOCUS, PURPOSE AND MENTORSHIP

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Evolution of a Capstone Design Program: Changes in Focus, Purpose and Mentorship

Abstract

This paper traces the transition of the capstone design experience in the ocean engineering program at the U.S. Naval Academy from one based on student ingenuity to one that focuses on real-world problems of client sponsors with opportunity for design testing and even product development. The pros and cons of each capstone approach are identified, along with lessons learned and experience gained. Examples and highlights of the capstone design projects in each phase of transition are also reviewed to show how student teams have advanced from use of designer handbooks and the drafting board to dealing with the natural effects of the ocean realm and its surroundings.

Introduction

Long a single-major institution, the U.S. Naval Academy (USNA) established unique majors programs in 1970 including seven ABET-accredited engineering majors: Aerospace Engineering, Electrical Engineering, Marine Engineering, Mechanical Engineering, Naval Architecture, Ocean Engineering, and Systems Engineering. With establishment of these accredited programs came the necessity to provide a capstone design experience within each major. In all cases, engineering students (Midshipmen) at USNA are enrolled in a course dedicated exclusively to a capstone design project during the last semester of their curriculum.

The primary author assumed coordination responsibility for the capstone program within the ocean engineering major in 1983 and oversaw the program until 2002. Since that time, either one of the co-authors has assumed that responsibility each year. With this background, we wish to discuss the evolution of the program and the rationale for changes through the years.

The Early Years (1972-1982)

In early years, ocean engineering students were tasked to develop formal proposals from lists of potential design projects suggested by various instructors. Such proposals would include not only an appropriate tasking statement to define project purpose but, also, the students' best estimates of environmental and performance parameters. The proposal, project objectives and design parameters were reviewed, modified when necessary, and approved by faculty mentors. Design teams typically consisted of 2-3 students. End-of-semester presentations were made to the group of professors mentoring the designs. Among the projects were the design of a one-atmosphere dive suit, an underwater habitat, and development of a local shoreline. Projects were challenging, but not necessarily real-world driven.

The Competitive Years (1983-1993)

The principal author joined the USNA faculty in the spring of 1983 and was assigned sole responsibility for the capstone design course. Rather than solicit proposals from the students, the instructor chose to develop specific tasking statements based on his experience as a Civil

Engineer Corps (CEC) officer and his insights to ocean engineering developments of Navy interest. Among the project taskings were upgrades of Navy pier facilities (both domestic and overseas), offshore tower and underwater range installations, and even modification of the U.S. Army's Bradley Fighting Vehicle so that it could forge streams subsequent to an armor weight addition. Other design project tasks included shore restoration schemes for east coast beaches (based on Army Corps of Engineers' proposals), and replicated designs for a remote Naval harbor facility or offshore fuel terminal. In most every case, the design task involved development of a feasibility-level design based on task objectives and available site information.

The typical capstone design class size was 30-40 students who would team in groups of 3 or 4, making for a total 10-12 design teams each year. These design teams were mentored typically by one or, at most, two instructors. Multiple design teams were assigned to each project, in part, to limit the focus of mentorship but also to make for a competitive design environment. Realistic estimates of environmental, performance, and economic parameters were provided in one-on-one sessions between a single design team and the instructor with the latter serving as client, engineering consultant or construction supervisor depending on the design team's progress and immediate area of concern.

Each team was allocated a design budget which varied based on type and size of project and could be expended in consultations with various department faculty, as needed. Faculty were free to set their own consultant fees; e.g., $50 per ¼-hour consultation. The fee structure provided an incentive for design teams to refine their requests before contacting a consultant. Many a time, a design team's request for information was returned unanswered due to unspecific site information or, worse, charged for information requested but irrelevant to the design task at hand. Such transactions frustrated the design teams but provided for better understanding and appreciation of the design task and roles of the various 'players' with whom the design engineer is likely to interact. Engineering fees were also charged against team budgets for 'labor hours' expended by the various team members, While charging (and justifying) labor hours seemed a disincentive to managing budgets, it provided a useful means to assess each member's contributions to the team's design effort.

At semester's end, each design team would present the results of their efforts to a Panel of Reviewers consisting of professional engineers and naval officers (external to USNA) familiar with ocean engineering and construction. Because multiple designs were prepared for each design task, Panel members could evaluate not only the engineering feasibility and accuracy of each design proposal but also the relative merit of each approach with respect to competitive designs. Students benefited as well from this competitive-design scenario by witnessing the Panel's assessments of alternate approaches to their task.

Age of Diversification (1994-2004)

As students in the ocean engineering major became more environmentally aware, the curriculum was revised to include a greater emphasis on ocean environmental engineering topics. An environmental engineering sub-specialty track was developed including environmentally-focused elective courses and capstone design projects dealing with the harvesting ocean energy, shoreline restorations with wetlands enhancements, among other environmental issues.[1] The net effect of this ‘environmental movement’ was a sudden increase in enrollment to 60-70 students in the capstone design course. Mentorship responsibility was expanded to multiple instructors, each of whom possessed a special area of expertise and a unique experience base.

One new faculty mentor (and co-author) possesses significant expertise in coastal engineering and holds close ties with the Army Corps of Engineers. Soliciting potential project ideas from contacts in that organization as well as from local Naval facilities, he has developed many shore enhancement and protection projects for the capstone design experience. Example projects include the design of a sand bypassing system for the Cape Henlopen (DE) shoreline, a shore stabilization plan for a local Navy installation, a shore protection system for local Coast Guard Station, and a timber fishing pier for a local community park. Key features of these projects, and many others, have been an emphasis on ‘real-world’ requirements and the close proximity of project sites to USNA. As a result, students are strongly encouraged to visit the site and to interact with the public-sector clients and local residents. The fee-structure experience was discontinued in favor of gathering and assessing real needs and actual site data. However, the assignment of multiple teams to the various projects was continued, and project sponsors have been included among the members of the Review Panel for assessment of student designs.

A second faculty mentor, also new to the capstone design course, had an expertise in underwater diving equipment and tools. He also taught an elective course in underwater work systems for those students interested in the deep ocean technology sub-specialty track in the ocean engineering major. He effectively used this fall-semester elective course to develop various design proposals critical to Navy needs. Such proposals included design of recirculating breathing systems, underwater tools for ship inspection and maintenance, and upgrading of facilities for NOAA’s “Inner Space” station, the Aquarius Underwater Laboratory off Key Largo, FL. Given his variety of research endeavors and interests, he would solicit one design team to work each proposal. Student designs were presented to the Review Panel which included his research sponsors who would critique the designs for real-world application. More often than not, such projects were revisited in future years to incorporate suggested enhancements and overcome perceived shortcomings.

The primary author took responsibility for mentoring the majority of the ocean energy-related design projects. He chose to discontinue the fee structure of earlier years to maintain consistency among mentorship of the various design teams. However, the real-world nature of the project tasking and the competitive aspects of design were retained on most designs. One project, in particular, is representative of the capstone design experience.

In 1998, the Navy was soliciting proposals from private industry to construct, operate and maintain the utility systems (for fresh water and power) for the Naval Support Facility (NSF) Diego Garcia, a remote island in the Indian Ocean. Coincident with private industry’s efforts, three design teams were tasked to develop an ocean energy system to satisfy the Navy’s requirements which included provision of 10 MW utility-grade electricity and 3,800 m^3/day of potable water. Each team evaluated various ocean energy possibilities including ocean currents, tides, waves, winds and thermoclines. In the end, each team concluded that ocean thermal energy conversion (OTEC) was the most favorable alternative. But, that was the extent of the similarity in their competitive designs. One student team suggested an offshore, moored floating plant using an open-cycle process. Another recommended a fixed offshore-based platform using a closed-cycle process. The third team proposed a land-based, closed cycle plant for power production and recommended that condensate condensing on the cold water pipe be used to supplement an on-shore desalination facility. The latter proposal was deemed most favorable by the Board of Review. Coincidentally, one of the private industry consortiums also proposed a land-based OTEC facility the Navy chose a conventional fuel-fire plant, in part, because of technological risk concerns.[2]

The increase in ocean engineering enrollment led to an increase in mentorship responsibility shared by multiple instructors with varied interests, experiences and expertise. The effect was a wider variability in project type and scope, and direct student involvement with more diverse DOD and other public-sector clients who were consulted for both project ideas and sponsorship. As detailed in a referenced paper[3], projects were local and real-world but, because of project scope, many of the design teams were still completing a feasibility-level study supported by engineering calculations.

Age of Experimentation (2005-present)

During the ocean engineering major's ABET accreditation review in year 2000, a deficiency was cited in the area of probability and statistics. Subsequently, two new courses were developed to supplement the major: EN330: Probability and Statistics with Ocean Applications, and EN486D: Experimental Methods in Ocean Engineering. Both courses encourage our students to become more involved in data collection and analysis, particularly in a laboratory setting. As student interest turned to more 'hands-on' involvement, many of the new millennium projects are not only real world but real substance. ASCE's concrete canoe competition, the Navy-sponsored autonomous underwater vehicle (AUV) competition, and a fish-tag study are but a few examples. Student teams remain responsible to address all phases of the design process including problem definition, data gathering, concept generation and assessment, and project designs are still presented to the Panel of Reviewers; but, many of the paper studies of the past have given way to more laboratory testing and experimentation and, when feasible, product development.

Enrollment in the major had dropped back to 35-45 students per year during the latter half of our "Age of Diversification" as other engineering majors adopted an environmental theme and included more design-build type projects such as the Mechanical Engineering Department's Formula SAE Car and Racing Lawnmower competitions and the Aerospace Department's Design-Build-Fly competition. However, the 'hands-on' opportunities and real-world nature of the recent ocean engineering capstone design projects has returned the major's enrollment to a desired 60-70 students per year.

Conclusion

The goal of this paper has been to discuss the evolution of the ocean engineering capstone design experience at the U.S. Naval Academy. Through the years, the program has evolved from one based on student ingenuity to one that focuses on real-world problems of client sponsors with opportunity for design testing and, even, product development. Whereas our program's primary objective has always been to provide our Midshipmen with a meaningful design experience, the recent focus is clearly to expose Midshipmen to 'real world' problems with opportunity to visit actual project sites, to consult with project sponsors and other interested parties, to assemble and interpret actual data, and to present their results to a Review Panel, the members of which have an expertise and, often, a personal interest in the project tasking and the results.

The opportunity to address real world projects provides a 'win-win' situation for both our students and the project sponsors with whom they interact. Our students develop a sense of pride in that their efforts are contributing to the future of ocean technology and, while they are not licensed professionals, their designs often serve as catalysts from which project sponsors can pursue additional funding or more formal designs. Most importantly, the students are gaining valuable knowledge and a practical understanding of the engineering design process which should serve them well in their later professional careers. Our efforts as their mentors have been rewarded as many of our graduates comment that the capstone design course was the most memorable academic experience of their four-year undergraduate tenure at USNA.

Bibliography

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