Selection and Execution of Civil Engineering Capstone Design Projects at the United States Coast Guard Academy

Hudson Jackson, Kassim Tarhini, Corinna Fleischmann, Nathan Rumsey, Sharon Zelmanowitz
United States Coast Guard Academy, New London, CT

Abstract
Civil engineering students at the United States Coast Guard Academy (USCGA) must complete a capstone project as a graduation requirement. The main objective is to enable students to experience real life engineering problem solving, design, team work, project execution and management. To satisfy program and accreditation requirements, the projects must have certain components such as problem definition, research, scheduling, solution analysis, design and communication of results. To better prepare our students for their unique future roles as civil engineers in the Coast Guard, most capstone projects involve working with Coast Guard officers and civilian engineers in the field on actual Coast Guard projects. Project selection criteria include funding for site visits, a mandatory design component, a reasonable project schedule, realistic stakeholder expectations and a good match with expertise of the faculty advisors. The capstone design teams are provided specific instructions to guide them through the execution of their capstone projects. These guidelines include mandatory weekly progress meetings with advisors followed by documented meeting minutes that are disseminated to the project team including the advisor and the stakeholders; a final comprehensive technical report; a final notebook that demonstrates their progress throughout the semester which is provided as a reference to the sponsors; three poster presentations at various stages of the project; and a final presentation where the teams present to all stakeholders of the capstone project. The authors discuss the development and execution of successful capstone projects at the USCGA and provide strategies for meeting Program Educational Outcomes while ensuring projects are useful to the Coast Guard.

Introduction
Most universities have developed capstone design courses in order to meet the Accreditation Board for Engineering and Technology (ABET) requirements. The structure of these courses have evolved to incorporate changes in technology, needs of industry and changes in ABET requirements. For example, Yost and Lane [1] reported the evolution of civil engineering design capstone experience at a research university, discussed measures to assess communication competence, and reported lessons learned while working with industry partners. They developed a capstone course designed to provide a unified effort in developing: teamwork skills, multidisciplinary interaction, communication skills, fundamentals of engineering design processes, and application of engineering design principles to a real engineering project. The course provided greater breadth in developing cost estimation skills, procurement of work, bidding versus quality based selection processes including a presentation of qualifications based on the project request for proposals, and how the design professionals, the client and the construction professions interact to construct a project. Kampf et al [2] reported about using practicing engineers and communications experts to not only provide feedback on the capstone design documents generated by students at the University of Minnesota, but they also assisted in
designing written assignment handouts that guided students through the project development process and presentations. They recognized that the students need to be able to shift from communication that has helped them succeed in the classroom to writing for complex audiences and making oral presentations in professional settings. Therefore, the role of consultants in the capstone project writing process has shifted from commenting on papers to presenting information focused on guiding students through the writing process, and helping students with their presentations. Ruwanpura et al [3] reported the organization of civil engineering capstone course that embodied a very significant international component and the difficulties inherent to that component. The novel approach adopted for the capstone project was to use the largest urban renewal project in Europe. Students had the opportunity to design major elements of the urban renewal scheme as part of the capstone project course. Sixty three students participated in preparing a design proposal for a full-scale urban renewal development in Lisbon, Portugal. The students had to learn about Lisbon which has different architectural and construction regulations, a different culture and history, and a different business culture. The students gained an opportunity to be immersed in an international, real-world experience that will be invaluable to their development of design concepts, analysis, and critical thinking.

At the United States Coast Guard Academy (USCGA), the Civil Engineering faculty work together with Coast Guard personnel at field units to identify real engineering projects for use as capstone design projects. This collaborative approach ensures that we fulfill our dual role of developing Coast Guard Officers and Civil Engineers through a total design experience working on an actual Civil Engineering project with engineers in the field. When possible, one or two non Coast Guard projects that are community based are included in the choices. Engineering projects that serve the community are an excellent way to introduce students to real world projects and to allow them to serve the public in the spirit of their chosen career path. This paper focuses on the process used in the selection and execution of capstone design projects at USCGA.

**USCGA Civil Engineering Program**

The USCGA is a small undergraduate institution of approximately 1000 cadets (students) with eight majors and approximately 15-20 percent of the cadet corps graduating with a Civil Engineering degree. Graduates pursue a number of different career paths and many of them serve in the Coast Guard as practicing civil engineers, pursue professional licensure, and attend graduate programs in Civil Engineering. The Civil Engineering program educational objectives are to produce graduates who:

1. Are prepared for professional practice in engineering positions as U.S. Coast Guard officers.
2. Are prepared for a variety of U.S. Coast Guard career paths, based on their abilities to apply fundamental engineering principles in a dynamic technological environment.
3. Have the ability and desire to continue to grow intellectually and professionally.
4. Are prepared to provide appropriate civil engineering expertise to the U.S. Coast Guard.

The Civil Engineering curriculum at the USCGA includes a variety of required core courses in the humanities, science, engineering, mathematics, professional maritime studies, organizational behavior, management, leadership and law. The curriculum is broad and provides a solid background in the structures, environmental, geotechnical, and construction sub-fields of civil engineering. All cadets must graduate in four years unless an extension is granted by the Superintendent and these cases are exceptional.
Capstone Experience at USCGA

In the late 1990s, the engineering department at USCGA initiated a comprehensive assessment program to address the new accreditation criteria established by ABET EC2000. This assessment process led to a number of curricular improvements, enhanced student learning and an educational program that better meets the needs of the Coast Guard. As a part of the assessment process, each course is subjected to an End of Course Review (EOCR) process where assessment data focused on achievement of the various educational outcomes (ABET Criteria 3 and 8) are reviewed and discussed with recommendations for course improvements. In 2000, as a result of the EOCR process, the Civil Engineering faculty created the framework for today’s capstone course based on student end of course surveys, constituent focus groups, senior exit surveys, and faculty observations.

The current capstone design course, CE1402 Civil Engineering Design (CED), was developed to mimic the civil engineering experiences students will face when they enter the engineering workforce after graduation. While this capstone course model continues to develop with each successive year, assessment data shows that course and program objectives of graduating students who can “plan, design, execute, and manage a complex open-ended civil engineering project” are being met [4]. In accomplishing this goal, students produce engineering design documents, construction drawings, cost estimates, construction schedules, and any other necessary project specific documents. In addition, students communicate the results of their project via a technical report and a formal presentation to their client. Over the years, it has become apparent that proper project selection and scoping is essential to achieving the educational outcomes defined for the course while ensuring that the project is useful to the client.

Project Selection Process

The USCGA has a unique partnership with the Coast Guard Civil Engineering Units (CEU) and Facilities Engineering Divisions of Coast Guard units located throughout the United States. These units are committed to the goals and mission of the Academy in providing leaders of character that are professionally prepared to serve as officers and engineers. They continue to support the USCGA in providing real life projects as well as funds needed to visit the site and complete the project work. Non-Coast Guard projects are usually community based efforts. Projects vary in complexity, but they all provide students with real exposure to the design, planning, supervision and management of actual civil engineering projects.

The capstone project selection process includes faculty consideration of constituent and student feedback, the ability to locate “real world” projects that can be successfully completed in the allotted single semester timeframe, and availability of funds. Project criteria such as funds for site visits, mandatory design component, project schedule, realistic stakeholder expectations, and the expertise of faculty advisors weigh heavily in the selection process. A schematic of the selection process is shown in Figure 1. After a temporary list of projects is generated, the projects are grouped by discipline. Effort is made to have at least one project in each civil engineering subfield-structural engineering, geotechnical engineering, environmental engineering, and construction or multiple combinations of these depending on faculty interest and expertise.
Figure 1: USCGA Capstone Project Selection Process
Projects with no design components are rejected if such components cannot be added by the faculty or capstone course instructor. Our capstone projects are usually done during the spring semester. Students are organized in teams and have fourteen weeks to complete their project. Evaluating stakeholders’ expectations against this timeline is crucial. Ensuring a reasonable timeline has resulted in some projects being split into subcomponents to ensure timely deliverables. As part of the capstone experience, each design team visits the project site; evaluating the availability of the required funding also plays into the final stage of the selection process as shown in Figure 1. Finally, it is verified that each subfield, or combinations of subfields, and different regions of the country are represented in the final stage of the process. This final step is not always successful depending on the initial list of projects available.

However, this is an important component of the process in order to maintain rapport with Coast Guard Civil Engineering field units. Variety of project types and engineering unit locations provide students with a better perspective of Coast Guard engineering operations. Examples of projects that have been selected over the past 3 years are as follows:

1. Relocation of Coast Guard Integrated Support Command Center in New Orleans, LA - Investigation of levee stability and design of a floodgate (2008). Cadets were tasked to develop a 30% design for a floodgate to the new NOLA-ISC in New Orleans, Louisiana. Cadets had the opportunity to collaborate with NASA, US Army Corp of Engineers, New Orleans Levee Board and Coast Guard engineers. Students incorporated new flood protection specifications proposed by US Army Corp of Engineers in their floodgate design and selection. Sponsor: Atlantic Facilities Design & Construction Center.

2. Analysis of storm water flow and quality and the impact of planned construction at the lower cadet parking lot at the USCGA (2008). Students analyzed the current storm water system for an existing cadet parking lot and evaluated the feasibility of adding additional flow from planned construction. They also developed a testing and analysis program for storm water pollutants generated at the USCGA. Sponsor: USCGA Facilities Engineering Division.

3. Development and testing of treatment systems for various wastewaters containing heavy metal contamination at the USCGA (2009). Students researched several systems for removing heavy metals from various wastewaters generated at the USCGA. They identified the most promising options, conducted lab experiments, and designed field scale systems. Sponsor: USCGA Facilities Engineering Division.

4. Replacement of CG Sector San Francisco Wave Attenuator - Review of several alternatives (2009). Due to aging and high cost of maintenance, students were required to look at several options to replace the wave attenuation system at Sector San Francisco. The group researched and developed alternative solutions and compared them with those proposed by an A/E firm. Sponsor: CEU Oakland, CA.

5. Mitchell Beach Restoration - Design and construction of a boardwalk along Mitchell Beach, New London, CT (2009). Students were required to design a 600 ft long barrier and boardwalk on the eastern end of Mitchell College campus along the Thames River. Students had to address problems of erosion and invasive plant species. Sponsor: Mitchell College, New London, CT.

6. Replacement of Hudson River Lights, Saugerties, NY - Investigation and repair of navigational lights along the Hudson River (2009). Students were required to address foundation deteriorations and erosion of riprap base of two light towers along the Hudson River. The project offered exposure to damage assessment, design challenges, permitting requirements and a constructability review. Sponsor: CEU Providence.
7. **Sustainability within the USCGA-**Develop and implement sustainable technologies at the USCGA (2009 & 2010). This multi-year project began in 2009 with one cadet team assigned the task of determining the necessity and feasibility of implementing sustainable engineering technologies at the USCGA. The 2009 group spent time researching project implementation at other New England campuses (mostly similar sized colleges) and completed a small design for the USCGA campus. The 2010 group, based on the previous year’s research, chose a different, larger site on campus and, with additional research, will complete a 35% design for a model sustainable classroom. Sponsor: USCGA Facilities Engineering Division.

8. **Coast Guard Green Ranking Assessment Standardization System (2010)—**Within the Coast Guard there existed no standardized way of comparing the state of sustainable practices among various CG shore units so that scarce resources could be put to best use. Students working on this project created and tested an assessment system that resulted in a concise and standardized sustainability and energy assessment summary. Sponsor: Coast Guard Civil Engineering Headquarters.

9. **Coast Guard Deepwater Cutter Allocation to CG Station Panama City, FL (2010)-**Shore facilities at Station Panama City, FL were inadequate to support two Fast Response Cutters (FRCs) scheduled to arrive in 2015. Students created Coast Guard internal planning documents (Planning Proposal) to prepare the waterfront and associated support buildings for the FRC arrival. The project required extensive review of facilities requirements, completion of a gap analysis, alternative development, permitting, and design. Sponsor: CEU Miami.

**Project Execution**

After the final project list is created, students are then allowed to list their top project choices via a “dream sheet.” Students with similar interest are grouped together into teams to work on one of the projects sponsored that year. This process occurs in the fall semester during their Construction Project Management (CPM) course. When they receive their teams and projects, each cadets completes a research paper on an aspect of the capstone project as a part of the CPM course. In CPM, project planning and execution principles are introduced that will be applied in the spring semester when they complete their capstone projects.

The capstone experience is designed to provide a forum to practice the art of engineering under conditions encountered in engineering practice. Students work in teams of three to five cadets and they are in charge of the project. Course coordinator, faculty advisor, and sponsoring personnel serve as consultants to the team(s). Students are provided specific guidelines and project management techniques to help them produce professional results in the format used in engineering practice. Each project needs to be divided into tasks, including a preliminary site visit to investigate the project, mandatory discussions with stakeholders, development of an acceptable solution, and a cost analysis. As deliverables, cadets give several oral presentations, three progress reports, and a final technical report. Guidance is provided in several forms, including (1) guidelines about technical reports and presentations, (2) lectures by the course coordinator or outside speakers, (3) weekly team meeting with project advisor, (4) feedback from faculty after two oral progress presentations, and (5) technical comments on two or three progress draft reports.
At the completion of the projects, cadets would have generated several documents including detailed technical reports, design drawings and contract documents depending on the requirements of the client. Emphasis is placed on following the Coast Guard (or other applicable) guidelines, relevant codes and other specifications where applicable. Guidelines and deliverables for each project team include for example; weekly progress meetings with advisors followed by documented meeting minutes that are disseminated to the project team, the advisor, course coordinator and the stakeholders; a final comprehensive project report, a project notebook that demonstrates their progress throughout the semester (provided as a reference to the sponsoring civil engineering unit or sponsor), three poster presentations of project status, and a final presentation to all stakeholders of the capstone project.

In 2007, additional changes were implemented to ensure that students stayed on schedule and to provide a more thorough and consistent grading format across projects. These changes included mandatory weekly progress meetings with a written progress report where the role of the lead engineer rotates weekly. A more comprehensive set of technical writing guidelines were also developed, with the assistance of the cadet writing and reading center director, to help cadets progressively develop a professional final technical report with draft chapters due on a prescribed timetable. Other deliverables, such as posters and “planning assignments” were also standardized with guidelines and grading rubrics to ensure that the expectations of each cadet team were standardized for the course. The aspect of the projects that require the most significant oversight is the management of large cadet teams. It is essential that faculty advisors encourage full participation of each group member and that each member can be assessed on their individual contributions as well as their ability to function as a member of the team. One technique that has been used with large teams is to assign each student a primary area of responsibility within the project. They are to become the “experts” in their area and to do the primary work in that aspect of the project while soliciting help from teammates as needed. As a part of our continued development of assessment tools, the faculty is developing tools to assess how well students engage in interdisciplinary team work. These tools will be applied to the capstone teams as they are developed.

**Conclusions**

Due to the demands of developing Coast Guard Officers and engineers in a four year period, internships and other real-life engineering exposure is limited for cadets at the United States Coast Guard Academy. As such the required capstone design experience is essential to achieve educational outcomes, tie together the various sub-fields of Civil Engineering, and provide vital real world engineering project experience to all of our students. Our capstone course has also evolved into a unique opportunity to forge mentorships between cadets and engineers in the field. The students always are excited to work on real projects that could help the Coast Guard or the local community meet engineering challenges. Now that the course includes many diverse real-world projects across the nation with actual clients, project selection and scoping has become key to ensure that educational outcomes are met while maintaining productive working relationships with the Coast Guard units and communities that we serve. Our current course format with regular progress reports and other deliverables has helped a great deal in keeping students on task and in helping faculty assess student work while applying a consistent grading scheme despite the differences among projects.
References


Authors Biography

Hudson Jackson: Dr. Jackson received his PhD from Rutgers University, New Jersey in the area of Geotechnical Engineering. He is a registered engineer in the State of PA, has over 18 yrs of experience in consulting and academe, and is currently an Assistant Professor of Civil Engineering at the U.S Coast Guard Academy, New London, CT. Hudson.V.Jackson@uscga.edu. Tel: (860)-444-8315.

Kassim Tarhini: Dr. Tarhini received his PhD from the University of Toledo, Ohio in Engineering Mechanics. He is a registered professional engineer in the state of Ohio, Nevada and Connecticut. He is currently a Lecturer, United States Coast Guard Academy, Kassim.M.Tarhini@uscga.edu.

Corinna Fleischmann: LCDR is a Lieutenant Commander in the United States Coast Guard, a registered professional engineer in the State of Florida and is currently a PhD candidate at the University of Connecticut. She is an Assistant Professor at the United States Coast Guard Academy, New London, CT. Corrina.M.Fleischmann@uscga.edu.

Nathan Rumsey: LT Rumsey is a Lieutenant in the United States Coast Guard. He received a M.S. in Civil Engineering and MBA from the Georgia Institute of Technology and is currently an instructor at the United States Coast Guard Academy, New London, CT. Nathan.L.Rumsey@uscga.edu.

Sharon Zelmanowitz, Dr. Zelmanowitz received a PhD from the University of Wisconsin – Madison in Civil and Environmental Engineering. She is a Professional Engineer in the State of New York and is currently Professor of Civil Engineering at the United States Coast Guard Academy where she has served for over 18 years. Sharon.Zelmanowitz@uscga.edu.