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USMA Regionalized Drinking Water Treatment Facility Multidiscipline Capstone

Ronald W. Welch, Steven D. Hart
United States Military Academy

Abstract

Last spring, 95 civil (CE) and environmental (EV) engineering majors in the ABET-accredited CE and EV programs at the U.S. Military Academy (USMA) worked on a multidisciplinary capstone project to design a regionalized drinking water treatment facility for West Point and surrounding communities. This paper assesses the project through student comments and instructor evaluations. The one-semester project responded to a real community need. The environmental engineers determined the treatment process type, treatment basin size, and treatment stream layout in plan and elevation. The civil engineers performed structural design of the treatment tanks, layout and design of the structure surrounding the treatment stream, and overall site analysis and design. The students quickly realized that their counterpart group (CE or EV), not the instructor, was the primary contact for key information beyond the client's concerns and needs. Students in both groups often found themselves waiting on the other group to complete work before they could proceed. While frustrating, they experienced the intricacies of multidisciplinary problem solving. In a typical class design project, students are provided a floor plan, a primary construction material, and specifications that allow them to focus on the technical aspects of the design. In this capstone project, students were responsible for defining the problem themselves (i.e., construction materials and building layouts) before they could complete the design.

A significant challenge was that the CE and EV students were in two different courses meeting at different times with different instructors. Accordingly, due dates were coordinated and class schedules adjusted such that both groups were learning the required skills and submitting assignments to support each others' design efforts. Some of the many insightful comments were that the final design revolves around the customer's desires, not the designers, and that the groups must be fully integrated with the CE/EV students working on the same team, submitting the same report, and receiving the same grade.

I. Introduction

The ABET-accredited Civil Engineering Major at West Point (USMA) consists of a common core of 25 courses in science, mathematics, and humanities taken by all students, regardless of major, and 18 discipline-specific courses in mathematics, science, and engineering. The Department of Civil and Mechanical Engineering administers the CE Major, while the Department of Geography and Environmental Engineering administers the EV Major (also ABET-accredited). A significant strength of the major is that it is a program of 18 inter-related courses each of which builds on knowledge acquired in previous courses. The culmination of the CE program is CE492, Design of Structural Systems, that everyone calls "The Capstone".

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CE492, while taught to each class of Civil Engineering Majors, is a different course each year. The students receive instruction in advanced structural topics including composite floor design and steel frame connections as well as instruction tailored to the current year's design project. This project specific instruction has included one or more of the following: concrete tank design, earthquake load calculations, plate girder design, and sloped roof design, etc. The in-class instruction occurs on about half of the 40 lessons available in the term. The remaining lessons are "open time" to allow the students to focus on the most significant component of the course—the semester long, comprehensive, design project.

The design experience in CE492 may take several forms, but is always a team project of sufficient size that each member of the team must assume a specialized role and perform the engineering duties of that role (i.e., structural, geotechnical, hydraulic, environmental, etc.). Usual areas required to complete the design include architectural considerations, site layout, structural analysis, structural design, foundation design, runoff analysis, and specialized component design.

II. Project

The spring of 2000 saw an innovative addition to the CE492 design experience. The civil engineering majors from the Department of Civil and Mechanical Engineering teamed up with environmental engineering majors from the Department of Geography and Environmental Engineering to design a regionalized drinking water treatment facility for West Point and the surrounding communities. Prior to this capstone course, these cadets had very limited interaction with each other and the other department. The joint capstone design responded to a real world need to modernize the three 50-year old water treatment facilities within the community that will soon be unable to efficiently meet community needs, as well as to address significant water resource management issues in the region. The joint capstone required the environmental engineers to determine the type of the treatment process, size the treatment basis, and layout the treatment stream in plan and elevation. The civil engineers were required to perform the structural design of the treatment tanks, layout and design the building around the treatment stream, and perform an overall site analysis and design.

The clients were the Town of Highlands Supervisor (Highland Falls, NY, and Fort Montgomery, NY) and the Director of Housing and Public Works (DHPW) at West Point, NY. West Point has two water treatment plants, Highland Falls has one water treatment plant, and Fort Montgomery has well service. Another major consideration for the design is that West Point owns most of the watershed area surrounding Highland Falls and Fort Montgomery and, therefore, controls most of the available water resources.

III. Challenges

The design of a regionalized water treatment facility presented several challenges to both the CE and EV groups. In a typical engineering design problem (EDP), the instructor acts as the customer or facilitator in providing outside information on the project. The students soon realized that for this design, their counterpart group and a real client, not the instructor, were their primary contacts for outside information. There were eleven civil engineering teams and six environmental engineering teams. This meant that each environmental engineering team was responsible for coordinating with two civil engineering teams. Students in both groups often found themselves waiting on their counterparts to complete work before they could proceed. While this was sometimes a source of frustration, it was a good initiation into some of the real world challenges of a multidisciplinary problem.

For all civil engineering design problems prior to the capstone course, the course director formulated the problem statement and scope of work for the students. Students were typically provided with a floor plan, a primary construction material, specifications, and scope of work that allowed them to focus primarily on the technical aspects of the design. In this capstone project, students were responsible for defining the problem themselves (i.e., construction materials, building layouts, limitations, and customer requirements) before they could complete the design.

A significant administrative challenge was that the environmental and civil engineering majors were in two different courses offered by two separate departments. The courses met at different times with different instructors. Accordingly, report formats, grade plans, and due dates were different. In an effort to alleviate potential problems, the instructors for the two courses did some very specific coordination prior to the start of the term. Due dates were coordinated and class schedules adjusted such that both the environmental and civil teams were learning the required skills and submitting required assignments to support the other teams.

Because the students were inexperienced in this type of multi-disciplinary work, the instructors developed an initial schedule of required information exchanges (Table 1) to ensure that much of the required information was changing hands in a timely manner. Since the groups were

Table 1. EV490/CE492 Capstone Coordination Schedule

Lesson #	Information & products Environmental Groups provide Civil Groups	Information & products Civil Groups provide Environmental Groups
4	Joint Site Visits	
8 (required meeting)	Process description, functional requirements, estimated volumes, estimated overall building size and layout, scale of site survey required to complete EV design work. (Based on homework 3 and feedback)	Common bay size (what can I span), What type of other information do I need to proceed.
13 (required meeting)	Process footprint (plan view) with tank sizes and flow paths and volumes between tanks, ancillary requirements such as materials storage, special rooms for chemical handling, delivery vehicle access.	Site survey (topographic) map with elevations, proposed overall site layout with access, structural, and drainage considerations.

dependent on each other for critical information, it was important that a given group did not delay a counterpart's work. On the first day of the term, this schedule was provided to each team explaining the required cross group meetings and what information was to be exchanged at each meeting.

IV. Student Assessment

As part of the end of course survey, CE students were asked to self assess the contribution of this multidisciplinary capstone to their education with the following questions. A sample of student responses is included.

- **My fellow students contributed to my learning in this course**

Strongly agree	49%
Agree	40%
Other	11%

- **I am able to develop feasible alternatives for a building and site such that all functional requirements are satisfied and the structural design is consistent with the architectural design.**

Excellent	31%
Satisfactory	53%
Good	12%
Other	4%

- **Please comment on the architectural and structural portions of the capstone design. Was it about right? Clear guidance? Good project? Bad project? Too much? Too little?**

    - 71 percent felt the capstone requirement was a good project for the following reasons:
        - There was good guidance that let us really work on our own instead of holding our hand through it. I liked that.
        - Good project. The guidance was good enough for us to use our creativity and come up with our own solutions.
        - I liked the architectural part. At first I was unsure of what to do, but then once I got the hang of it, I really enjoyed it. I think it mirrored what I would find in a real life situation.
    - 29 percent felt the capstone was a bad project for the following reasons:
        - A lot of times the guidance was not clear.
        - Not possible for us to do everything in a design in one semester.
        - We should not have to design what the building looks like – we are engineers.
        - Did not like EV group interaction.

- **Concerning the capstone design, what did working with the environmental engineering group teach you about the interaction of various architectural and engineering disciplines?**

    - We were able to understand the importance of specialty engineers, as well as the importance of all engineers having a minimum level of common knowledge.
    - It teaches you that you must be able to convey your information in a way that makes sense to someone that doesn't have your subject matter expertise. So they know why you are designing something the way you are or why you cannot do something that they have recommended in their design because it is just not structurally feasible.
    - Interaction takes a lot of patience, coordination and good communication.
    - A project never requires JUST civil engineers.
    - It was good to see how people with a different focus view the same problem.
    - It is difficult to work with another discipline. It just complicated things.
    - Nothing, we just exchanged required information.
    - Nothing, they were late with providing us required information.

- **What would you change about the administration of the capstone design or the CE-EV group interaction?**

    - Instructors need to make due dates the same. When some due dates are slightly different, it is hard to get the other group to give you stuff because they have not worked on it yet.
    - I would have liked to have a better understanding of what the EV groups were doing and how we interacted with them.
    - Make more mandatory meetings between the two groups.
    - I would put more emphasis on the Memorandum For Record (formal recording of discussions in joint meeting) in both camps, as well as formal meetings.
    - I would make the EV groups require more information from the CE groups so that they need our work like we needed theirs.

Overall, this project went well. While the students on both sides sometimes became frustrated with their counterparts, they learned for the most part how to deal with these frustrations as part of multidisciplinary teams. Some students did not like the project for the very reasons that they need to gain an experience in multidisciplinary designs. The most significant lesson learned by the students was that the final design revolves around the customer's desires, not the designer's. CE students were able to integrate and apply aspects of most of their engineering courses to include hydrology, soils and foundations, reinforced concrete, structural analysis, steel design, surveying, and environmental engineering into one project to get a true feel for the complexity and scope of real world engineering problems.

V. Instructor Assessment

The key to success was the coordination between instructors prior to the semester to establish the required information handovers. Without this, many groups would not have been successful at all in working together.

The most significant weakness of this capstone experience was that the environmental and civil groups were not fully integrated. They were merely working in parallel with some pre-defined crossover points. This resulted in limited interaction and communication as well as fostering a "we-they" attitude. The instructors plan to act as project managers when the groups meet in future uses of this capstone model. There is a need for someone to ensure that the individual groups work as one team, i.e., the instructor or project manager.

Additionally, there was not a vested interest in making the counterpart group successful. In the future, both groups must be integrated with civil and environmental engineers working on the same team, submitting the same report, and receiving the same grade.

VI. Conclusion

The ultimate value of this project could be seen in the final briefing. The best performing design groups had the opportunity to brief the project to the potential customers, the Director of Public Works, managers of the local existing drinking water treatment facilities, and officials from Highland Falls. The briefing began with the environmental engineers laying out the requirements for the new facility. The civil engineers then presented the analysis of possible sites and were followed by the environmental engineers discussing the treatment stream. The civil engineers then completed the briefing by discussing building design, site layout, and project estimated costs. This one-hour briefing demonstrated the interdependence of the civil and environmental engineers in the design process and the multi-disciplinary nature of the project.

The "Capstone Course" is the most significant part of the West Point Civil Engineering Curriculum. It requires the students to draw from all aspects of their education, work on multidisciplinary teams, and succeed in an environment that is an academic approximation of professional practice. The keys for success in this type of class include a problem scope that can be completed in one semester, detailed instructions on information sharing between groups, and concentrated efforts by the instructor to ensure that students maintain the proper attitude and coordination throughout the project. The cross-department, multidisciplinary aspect of this project increased the level of preparation required on the part of the instructors, but paid off greatly in terms of student knowledge, understanding, and experience.

RONALD W. WELCH
Lieutenant Colonel Ronald W. Welch is an Assistant Professor and Director, Structures Group at the United States Military Academy (USMA). He is a registered Professional Engineer in Virginia. LTC Welch received a BS degree in Mechanical Engineering from USMA in 1982 and MS and Ph.D. degrees in Civil Engineering from the University of Illinois at Urbana-Champaign in 1990 and 1999, respectively.

STEVEN D. HART
Major Steven D. Hart is an Assistant Professor of Civil Engineering at the United States Military Academy at West Point, NY. He earned a BS degree in Civil Engineering from the United States Military Academy in 1988 and a MS degree in Civil Engineering from Virginia Tech in 1998. He is a registered Professional Engineer in Virginia and Georgia.