USMA CE Model For Client-Based Multidiscipline Capstones

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

Abstract

This paper describes a model used successfully by the ABET-Accredited Civil Engineering Program at the U.S. Military Academy (USMA) for client-based multidisciplinary capstone projects. The client has been the West Point Association of Graduates (AOG), which then represents USMA to provide the facilities and services only possible through gift projects, such as a non-funded sports team facility. The model consists of two phases: first, an independent study by three to eight students to define the project (i.e., 10 percent submittal - concept design); second, the civil engineering majors in multiple teams complete the design of the facility. The capstone designs developed by the multiple senior design teams provide the feasibility studies and/or architectural/engineering products required for marketing the project to potential donors. Work in other courses is completed concurrently to provide real time input to the design process.

I. Introduction

The climate in the New York area essentially prevents any effective outdoor golf training from mid-November to mid-March. The Academy had already identified a need for an indoor golf training facility, but the facility was such a low priority that it was not even on the list of authorized fund raising items. The Association of Graduates, the primary fund raising organization for the Academy, follows the Superintendent's (i.e., University President) lead as to the priority for fund raising projects.

It takes money to raise money. Any facility, including the indoor golf training facility, requires Architectural and Engineering (A&E) products to stimulate interest in the project and to establish the funding requirements for actual construction. A&E products can be up to 50 percent of the total project cost – an extremely large sunk cost if actual interest in the project does not lead to sufficient donations to cover initial and construction costs.

In this case, a prospective donor appeared on the horizon, but there were no A&E products or cost estimates to move the discussion beyond the general need and the "maybe I can help" level. In 1998, an academic advisor for the West Point Golf Team, who knew that the golf team's practice facility had a very low fund raising status, approached a Civil Engineering instructor. Since the Civil Engineering Division desired to develop new senior design capstone projects each year, the concept of using civil engineering students in the senior design capstone course to perform the initial A&E design work for a new facility quickly materialized.

The senior design capstone course, which is built around a semester-long comprehensive team project, integrates all aspects of the civil engineering curriculum. The civil engineering students, first through an independent study course of 3-8 students followed by the multiple capstone

design teams, addressed the financial, functional, and legal issues of the numerous clients through architectural models and drawings, structural designs, and cost estimates. The effort was so successful that this project, which previously was not receiving any funding to generate donations, is funded to begin construction in the near future.

With this model, the clients were able to narrow down what they wanted in the final structure through interaction with the cadet teams and review of their products. The clients provided the actual A&E firm with a very refined concept by using portions of multiple design team products. The A&E firm was then able to quickly provide finished products for construction. The added benefit of designing a structure to meet a real-world need, while addressing the ever-evolving individual and legal needs for such a structure, was an immensely valuable experience for the students. This was not only true for the students in the capstone design course, but also the students in other courses, such as the geotechnical course taken by juniors that provided soil analysis from a test pit on the future site, who acted as consultants for the seniors on the project.

This endeavor was so cost effective for AOG that they have again requested the civil engineering students to provide the initial A&E products and cost estimates for another low priority but much needed facility: A Rugby Stadium Complex. Three students (one a rugby player) established the 10 percent submittal (design concept) through an independent study project in the first semester. The independent study group coordinated and worked with the fund raising committee, the Superintendent, the coach (or activity director), AOG, possible donors, and the Director of Housing and Public Works to ensure that the project met the needs of all concerned. In the second semester, the civil engineers were broken down into multiple design teams to provide the final products used in the fund raising effort. Each design team was provided different constraints (cost, size, types of rooms, etc.) to force the development of different options to assist in defining the final product based on cost, functionality, and possible fund raising success.

II. Model

The client-based model consists of two phases: first, an independent study by three to eight students to define the project (i.e., 10 percent submittal – concept design); second, the civil engineering majors complete the design of the facility during the senior design capstone course. Work in other courses is completed concurrently to provide real time input to the design process.

In the first semester, the independent study group coordinated and worked with all the clients, whoever they may be. For past projects at USMA, the clients consisted of the fund raising committee, the Superintendent, the coach (or activity director), AOG, known donors, and the Director of Housing and Public Works. Some of the issues considered during the 10 percent Concept Design submittal were construction permits, funding, safety, zoning variances (i.e., the Coastal Zone Management Office (New York) for development along the scenic Hudson River, the State Historical and Preservation Office – USMA is a historical site, etc.), functional requirements, building codes, USMA guidance (i.e., aesthetic, multi-use, etc.), desired structural systems, limitations and constraints. The products were a list of functional requirements, a list of aesthetic requirements, a list of code requirements (UBC and Installation Design Guide), floor plan(s) for all floors, exterior elevation views for all sides, a general site layout, and a list of the specific impacts on the problem (soil conditions, utilities, special site restrictions, etc.). The

resulting products were much better design requirement handouts than the instructor alone could ever produce.

In the second semester, the multiple design teams of four or five students produce design submittals that provide: the site layout to include surveying, the foundation design, the structural design, the hydraulic design, the architectural scheme, the cost estimate, a physical model, a display board, and a project report. Each design team was (can be) provided varying design constraints that are caused by possible fund raising or lending limits. Each design team submits 10, 35, 65, and 100 percent products during the semester (Table 1).

Table 1: List of Important Products in Each Submittal

10%	35%	65% IPR	100%
Functional & Aesthetic requirements	Finalized functional and aesthetic requirements	Review progress rom 35% toward 00%.	Finalized drawings including site, floor, and elevations, floor framing, roof framing, and lateral load systems.
Architectural Adjacencies drawing	Finalized floor, site, and elevation drawings	Expect about half of esign work to be ompleted	
Floor plans	Written structural scheme with drawings of column lines and framing concepts, lateral load resisting systems	Desk side brief with eview of calculations	Site drainage plan with watershed delineation and component design
Site Plan	Concepts for critical civil sub-systems: drainage plans, cladding and walls, foundations, problem specific systems, environmental systems		Structural systems design including, roof members, beams, girders, columns, beam columns, lateral load resisting systems, and sample connections design.
Exterior Elevations	Loads analysis		Selected element designs for column base plates, footings, foundations, and special sub-systems
Written structural concept	Cost estimates		
			Cost estimates by assembly

Throughout the semester additional input from and coordination with the client continues. At the end of the semester each team formally presents their design to the client. It is always possible that the client may desire to continue the project the following semester with additional variations to the design. AOG usually takes two or three teams' products that meet the minimum

needs and realistic funding levels to use for fund raising efforts. Work in other courses can be completed concurrently to provide real time input as consultants to the design process.

III. Input From Other Courses

In real practice, most design teams must wait and/or coordinate for input from experts, whether inside or outside of the firm, before completion of the design. In school, this can be simulated by integration of multiple courses into the design process to provide the most realistic scenario possible. As long as both project and curricular objectives are served, a number of different courses can provide input to the project in a synergistic effort.

Juniors generally take the courses that provide design input, but there may be some requirements best met by courses typically taken by seniors who are also in the capstone design course. Soil analysis for foundation design can be provided by the geotechnical course from a test pit on the future site. Rain data and required flow rates can be provided by the hydraulics course. Site survey can be provided by the transportation survey course. Environmental impact reports can be provided by the environmental course. Construction time estimates (i.e., CPM, etc.) can be provided by the construction management course. Other civil engineering courses could easily become involved in the process based on the unique issues of a given project. A truly multidiscipline capstone design experience (i.e., if a facility) could also include the mechanical engineers to design the mechanical and air-conditioning systems and the electrical engineers to design the power grid for the structure.

IV. Benefits

The major benefits of this type of design experience fall into three primary areas: client perspective, student perspective, and instructor perspective. The client receives initial A&E products at little to no cost, products that tremendously assist in finalizing the desired design. The products give visibility to projects that might otherwise go unnoticed. In this situation, prospective donors have physical models to assist in fully understanding the team's need and cost estimates to meet those needs. "Student Designed" products are very positive fund raising tools, especially with alumni. Once the required funding levels are met, the client with input from the donors can provide fairly detailed input to an actual A&E firm to produce lower-cost final design products.

The students thoroughly enjoy providing a design product for a real world need. They must contend with real challenges such as funding, site layout, and local restrictions. They tend to put more creativity into their effort since they know that it might make a real difference, especially at their own school. Add the realism of a client other than the instructor to the design experience and the capstone design course is a win-win experience for the student and client alike.

Anytime a real-world project can be used in the classroom setting, it greatly assists the instructor in developing a great design problem and it is so much easier to motivate the students to exceed the minimal standards. The importance of quality products is now easily understood by all of the students. However, project concept may be easier (the need), but the coordination with a true client during the independent study is time consuming and must be completed at the right level

and time (end of semester) to provide the proper input (concept design products) for the design teams the following semester. Sometimes there is conflict between the client's needs and the schedule/requirements of the semester capstone course. Occasionally, a good project may not challenge some aspect of the civil engineering experience, i.e., the required structural scheme is simplistic.

V. Student Assessment

Student assessments at the end of the experience were extremely supportive for the effort of conducting client-based multi-discipline capstone experiences. A few of the comments are provided:

- Working on a real project made the work meaningful instead of just another problem set or EDP (Engineering Design Problem).
- I enjoyed working on a real project and knowing my work could be used to help construct the project.
- I liked working with a real project because we were finally able to put everything together.
- Doing a real world project gave a sense of importance to our work that is just not there with another class project.
- I liked the course because we actually learned about the construction process.
- Maybe I'm sadistic, but I liked the project – it helps tie everything together.
- The very small external loads on the golf facility made design and analysis more difficult than imagined.
- I mean when people ask me what I worked on for my capstone I get to say, "a Golf Training facility – Hoooah!"
- Having a final goal that may actually be produced provides good motivation (importance).

There were some less positive comments suggesting a need to expose students to more ambiguous, open-ended problems earlier in their academic experience:

- Try and find a project more like what we have studied in the course.
- There was a large diversity in the material needed to complete the design.
- Difficulty dealing with the continual changes by the coach.
- A lot of time trying to learn something not covered exactly in the design references.
- The instructor did not seem to give much guidance.

One year the program did an instructor-based feasibility study with the environmental engineering majors on the design of a regionalized water treatment facility as opposed to the client-based model.[1] Some of the cadet responses were:

- I would have preferred to design a building such as the Arvin Gym renovation or maybe Washington Hall addition or something along those lines.
- I think I would have been more interested in the project if we had done something cool like the golf course facility from last year.

It may be deduced that if the facility is needed and will have an impact on the student population, it may receive the student focus all professors hope their projects receive.

VI. Conclusion

Student assessments show that this form of capstone experience not only challenges, but also motivates the students like no other experience since they are performing design work that positively impacts their school. The assessment also shows that this type of experience generates truly open-ended designs. The client gets preliminary design work for free and the school receives good publicity with and funds donated from alumni. When the students return for reunions, that facility will be one of the first places they will stop to show their families and say, "I designed this facility!"

Bibliography

1. Welch, R.W., S.D. Hart, "USMA Regionalized Drinking Water Treatment Facility Multidiscipline Capstone" *Proceedings of the 2001 American Society for Engineering Education Annual Conference*, American Society for Engineering Education, June 2001, Session 2793.

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.