Client-Based Projects for Every Senior – A Mark of Excellence for Any Program

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Abstract

This paper describes a unique senior project capstone course used successfully by the ABET-Accredited Civil Engineering Program at the United States Military Academy (USMA) to greatly enhance the academic program. The three general project classifications available within this senior project course are service-based (i.e., USMA, the Army, local community), competition-based (i.e., steel bridge, concrete canoe, timber bridge), and research-based. Many of these projects each year have design-build components requiring one to six students. The mix of these open-ended projects usually ensures that each student can list a minimum of 3-5 project choices that meet their individual needs for a challenging, yet rewarding academic experience – something for everyone! Most students list at least one, if not all, of the service-based projects. Some projects have multiple teams of students trying to sell themselves to the faculty advisor as the team of choice.

It will be shown through student assessment that this form of experience not only challenges, but also motivates the students like no other aspect of their academic experience. The students are providing a solution to a real world problem for a real client. The reverse is also true; student involvement in solving real problems and/or designing/building products stimulates the clients and sponsors to become heavily involved during the process. Increased client participation enhances not only the quality of the product, but the experience for the student and client. These semester-long projects are a great learning experience for all, including the faculty. The assessment will show that the students find the program demanding, but enjoyable and worthwhile, because it forces them to push the boundaries of the their knowledge through initiative, self-study, perseverance, and creativity.

I. Introduction

For over 30 years independent study projects have been offered to civil engineering students at USMA, but only to the top 2-3 students in the program. The projects focused on in-depth study in a specific civil engineering sub-discipline with the ultimate goal being greater student knowledge through self-study and only occasional faculty guidance. In the mid-eighties, the steel bridge and concrete canoe competitions were added as yearly projects. It became quickly evident that the right team with students possessing hands-on skills could not always come from the top tier of students. In fact most of the students wanting to be part of the competition experience were not in the top tier. Of course, faculty were concerned whether the students would be truly self-starters and able to complete the work required to design and then build the prototype for the competition, -- all in one semester. In the end, faculty advisors and students alike found the experience to be exhilarating, challenging, and just plain different from the normal academic experience.

In the mid-nineties with the addition of civilian faculty at USMA, research and scholarship activities gained greater focus and soon all faculty were spending more time on research, something that is currently occurring at many small, primarily undergraduate teaching colleges. The inclusion of undergraduates in faculty research was a natural extension of faculty research and a welcome addition to the list of available student projects. At the same time, many faculty were involved heavily within their community and knew of potential service-based projects that would equally challenge and educate the students. It quickly became obvious that many students would love the opportunity to put their skills to work and produce a product that met a real need.

In the fall of 1999, it was decided to more fully develop the civil engineering independent study program to ensure every senior CE major had the opportunity to participate in a open-ended project, in addition to the required program capstone experience, during the spring semester. Student assessment from the handful of students who could participate in previous years not only highlighted the value of the experience, but also the excitement they felt in providing a service to a real client. Therefore, all possible projects were evaluated and developed to produce a balanced list of projects consisting of the three general project classifications: service-based (i.e., USMA, the Army, local community), competition-based (i.e., steel bridge, concrete canoe, timber bridge), and research-based. The key is that **all** are client-based projects.

II. Projects

The Department of Civil and Mechanical Engineering is extremely proud of the variety and number of projects it provides for the students. Initially, there was some effort required to develop the requisite number of projects that ensured each student had the opportunity to work on a project and no single project had more students assigned than the required workload could support. Exceptional student work provided at little to no cost to the client has opened up a ground swell of projects now constantly offered to the program coordinator by prospective clients. A number of clients are repeat customers.

Many students continue research being conducted by the faculty and/or at Army Labs. However, a large number of projects each year are associated with some type of national competition or provide a needed service to our local community. With an average group size of two to four students, each project requires each student's contribution, cooperation, and expertise, while allowing maximum student, client, and faculty advisor interaction.

The mix of open-ended projects usually ensures that each student can list a minimum of 3-5 project choices that meet his or her individual needs for a challenging, yet rewarding academic experience – something for everyone! A large number of projects, especially service-based projects, have multiple teams of students trying to sell themselves to the faculty advisor as the team of choice. Projects are presented to the students early in the fall semester of their senior year. Once the students have had a chance to conduct in-depth discussions with the project faculty advisors of choice (about two weeks time), the course coordinator requires each student to e-mail their rank order of preferred projects. Approximately 90-98 percent of the seniors each year choose to work on one of these open-ended projects that is running parallel to our program required capstone experience. Many have stated that it is like having two capstone experiences, but totally worth the experience. The ultimate goal for the course coordinator is to match the

right student with the right project while trying to give students one of their top five choices. Project assignments are made by mid-fall semester so that initial coordination and some preparatory work can commence prior to the spring semester. Each student has the right of first refusal and can opt for a project slot still available or can take another course. Usually there are not enough community service projects to meet the student demand. Some advisors actively recruit students for specific skills and project success. Key: every student has the opportunity to participate in a project even though it might not be his or her top choice.

a. Community Service Projects

Community service projects have been extremely valuable at educating the community about engineering and building ties with local organizations/communities.[1] These local organizations / communities receive a valuable service from the students in the form of a design, professional recommendation, and/or a working device at minimum to no cost. These organizations / communities have, in turn, informed other groups that have aggressively sought assistance from the department. Students learn to interact with community sponsors, many who have little technical training, and contribute to the local area in a meaningful way. Recent project sponsors ranged from sports clubs at the academy to a local humane society. Large funding requirements must come from the client, while small amounts, if the client has limited funds, come from our alumni organization, the Association of Graduates (AOG). A description of the Popolopen Brook Float Bridge [2] project follows.

The focus of the Popolopen Brook Float Bridge project (Fig 1) was to develop different design alternatives to span 230 feet of Popolopen Brook. The bridge will connect two revolutionary forts: Fort Montgomery and Fort Clinton. This bridge will be the most important link in making the Fort Clinton / Fort Montgomery Battlefield Site a complete historical site by allowing visitors easy access to both forts just as it was believed to have existed when the forts defended the

Figure 1. Float Bridge Full Scale Module Demonstration on the Hudson River

Hudson Valley during the Revolutionary War. The desired result was a feasibility study of each alternative. The military historian for the Hudson River Valley and Palisades Interstate Park Commission was the primary client and used the feasibility study to spark interest from a

multitude of funding sources to include the Governor of New York. The team designed and built one full scale float bridge module (Fig 1) that incorporated four design alternatives to assist the clients in deciding on the final design.

A complete list community service projects and clients over the last three years are in Table 1.

Table 1: Community Service Projects

Community Service Project	Clients
Academic Year 1999-2000	
Constitution Island Bridges	West Point and Constitution Island Historical Society
Popolopen Brook Bridge Feasibility Study	Mid-Hudson Valley Military Historian
Cableway Training Kit	Fort Bragg
Large Area Maintenance Structures Tie-down	Natick Labs
Church Steeple Analysis	Newburgh Church
Abatis Site	West Point Camp Buckner Training
Bridge Demolition	West Point Camp Buckner Training
Wall Breaching	West Point Camp Buckner Training
Academic Year 2000-2001	
West Point Lower Area Recreational Complex	USMA Housing Office
Walden Humane Society Renovation	Walden Humane Society
Popolopen Brook Float Bridge	Fort Montgomery Battlefield Site Ass.
Ground Water Study and Aquifer Model	USGS and Town of Gardiner, NY
Structural Evaluation of Church Bell Tower	St. George's Church, Newburgh, NY
Ice Jam Prediction Investigation	Cold Regions Research & Engineering Lab
Indoor Obstacle Course Load Testing	Department of Physical Education
Project Wrench	Department of Civil and Mechanical Eng.
USMA Parking Analysis	Department of Civil and Mechanical Eng
Rugby Facility Design	AOG, Army Rugby Team
Academic Year 2001-2002	
Catholic Chapel Annex	West Point Catholic Community
Appalachian Trail Foot Bridge	Palisades Park Commission
Wallkill Library Expansion	Town of Wallkill
Rehabilitation of Peace Bell Structure @ Washington's Last Encampment	Town of New Windsor
MOUT Site	West Point Camp Buckner Training
5-Story Skyscraper – Leader Reaction Course	West Point Camp Buckner Training
Weir/Bridge Design – Class '43 Gift Site	West Point Class of 1943
Stillwell Dam Flood Study	West Point and Town of Fort Montgomery
Stillwell Dam Assessment	West Point
Trebuchet	Department of Civil and Mechanical Eng

b. Competition Projects

Competition projects are conducted at regional and national levels. Funding for these projects is primarily through our alumni organization, AOG, and donations of skills, equipment, and materials from interested sponsors/clients, such as PDJ Components associated with the Timber Bridge Competition described below. These design, build, and compete projects usually involve various technologies and bring out the best effort in our students. Students not only become very knowledgeable about their project, but they develop well structured and organized competition design teams. Competition projects are highly desirable for the students since they are competitive by nature, but traveling and winning are high on the list as well. The ability to travel and participate in the national competition is always dependent on the quality and progress of their product. Teamwork and project management skills go a long way in these major design projects. A description of the Timber Bridge [3,4] competition is below.

The timber bridge competition is sponsored annually by Southwest Mississippi Resource Conservatory and Development (RC&D), Inc. and the U.S. Forest Service. The students design, construct, and load test a 13 ft long by 4 ft wide timber bridge. All timber must be treated for exterior use in accordance with industry standards. The bridge must be capable of holding a load of 5000 lbs with minimum deflection of all members. Evaluated events include a videotape of the construction and loading sequence, loading results, and a formal report with photos (Figure 2). The AY00-01 competition resulted in USMA being the 2001 National Champion based on the following places: 1st Place-Best Deck Design, 1st Place-Most Practical Design, 2nd Place-Willamette Industries Design Award, 2nd Place-Best Support Structure. An added bonus was the community service link after the competition, what to do with a bridge that could support 5000 pounds? The bridge has been incorporated into the West Point Elementary School nature trail project currently under construction. AY01-02 competition resulted in USMA placing 3rd overall.

Figure 2. USMA 2001 Timber Bridge

A complete list of competition projects is in Table 2.

Table 2: Competition Projects

Competition Project	Clients
AISC Steel Bridge Competition	AOG (2000, 2001, 2002)
ASCE Concrete Canoe Competition	AOG (2000, 2001, 2002)
ASCE National Timber Bridge Competition	AOG (2001, 2002) and PDJ Components and Roe Brothers (2001) and Hoover Treated Wood Products (2002)

c. Research Projects

Research projects give the students an excellent opportunity to participate in existing research at an Army laboratory or with a USMA faculty member. Many of these projects allow students to have access to data and computing facilities not available at USMA. Many research project sponsors are usually not in the local area, but an initial visit to the laboratory, constant communication, and any necessary follow up visits with the sponsor usually provide sufficient direction. Usually the laboratories can easily provide the required travel funds. Many of these projects allow our students to influence new Army technology that they may use after they graduate and enter the Army. A description of the project Modal Analysis of Blast Plates [5,6] follows.

Simplified structural-response models based on limited parameters are needed to facilitate vulnerability analyses of Army vehicles subjected to blast loading. Towards this end, blast tests using spherical charges have been conducted on flat panels (Figure 3). Parameters in the experimental study include charge weight, panel material and edge constraint. These experiments have been modeled using finite elements to assess the accuracy of finite element

Figure 3. Modal Analysis on Blast Plates

predictions by direct comparison with experimental data. Initial comparisons between experiment and prediction indicated errors in the finite element model. Simple analytical models

were constructed to verify the operation of the finite element models. Subsequent to this verification, an error in the modeling of boundary conditions in the analytical work was identified. Validated finite element models will ultimately provide a basis for studies to determine the most relevant parameters to be included in simplified response models for vulnerability analyses.

A complete list of research projects and clients from the past three years are in Table 3.

Table 3: Research Projects

Research Project	Clients
Academic Year 1999-2000	
Frost/Heave	Cold Regions Lab
Strengthening RC Beams with FRP	Army Research Laboratory
Ice Jam Prediction Investigation	Cold Regions Research & Engineering Lab
Academic Year 2000-2001	
Prioritizing Repair Projects -Locks and Dams	Construction Engineering Research Lab
Carbon Fiber Reinforced Plastics	Army Research Laboratory
Modal Analysis of Blast Plates	Army Research Laboratory
Watershed and Reservoir Study	Waterways Experiment Station
Auger Pilings Design for Large Area Maintenance Structures	Natick Labs
Mine Vehicle	Army Research Laboratory
Ice Jam Prediction Investigation	Cold Regions Research & Engineering Lab
Academic Year 2001-2002	
Reliability Analysis of Miter Gates	Construction Engineering Research Lab
Lightweight Concrete Modulus of Elasticity	Noorlite
Retrofit of Steel Structures with FRP	Army Research Lab
Hardened Structures Using Geologic Materials	Army Engineering Research & Development Center
Design Charts for Laterally Restrained Slabs	Department of Civil and Mechanical Eng

III. Projects Day

Since the spring of 2000, USMA has conducted Projects Day as an initiative to engage all of the academy's students and the local community in engineering design. It is unique since engineering excellence is supported and advertised by the institution rather than by one of the engineering departments. This distinction has encouraged its acceptance and promotion throughout the academy, including the non-engineering departments.

The Dean's Policy and Operating Memorandum states that Projects Day promotes academic excellence by providing senior students with a public forum to present their senior theses or design projects. [7] Projects Day is scheduled near the end of the Spring Term when most of the senior capstone projects are complete or near completion. Freshmen through seniors who have a free hour in their schedules are encouraged to attend Projects Day events, and a large number attend and actively ask questions at the end of the presentations. Additionally, the sponsoring

departments try to schedule presentations over several instruction periods during the day to encourage student participation. The department of Civil and Mechanical Engineering requires its sophomore CE/ME majors in Statics and Dynamics and the junior CE/ME majors in Structural Analysis/Intro to Mechanical Design to attend at least one presentation and prepare a journal entry. The individual departments also invite clients, project sponsors, community leaders, and local school children to attend the presentations as well. Current committee discussions are considering the inclusion of a non-class day three lessons before finals classified as Projects Day.

These senior projects represent the culmination of their four-year educational experience. Students begin their education as freshmen with highly structured courses and detailed requirements in the core program taken by all students. Not later than the junior year, each student begins an in-depth study within one of the majors offered at West Point. The academic experience normally ends with an open-ended, challenging real-life project often providing a service to a real client. Projects Day, when used as a stimulus in conjunction with teaching design, is a superb experience for those involved, giving students additional experience with teamwork and presentation of designs to a client with real concerns.

IV. Benefits

Project development, management, and presentation definitely require faculty buy-in and time, but the benefit to the program and the students is tremendous (Fig 4, 1-Low and 5-High). These projects assist the program in meeting ABET criteria in a way many other courses can not and to stimulate the students to develop and apply new skills beyond the boundaries of past courses to solve an ill-defined problem. The course objectives are:

- Apply the engineering thought process to develop a creative solution to an open-ended engineering problem.
- Produce a high-quality design/analysis/research report.
- Present a high-quality oral briefing.
- Prepare for life-long intellectual growth, through self-directed learning.

The addition of Projects Day provides a single focused day for presenting these wonderful solutions and evaluating oral communication skills. One of the indirect advantages of Projects Day is the number of faculty across the campus that become more aware of the department's projects. The visual conveyance and articulation of the projects have prompted many faculty members from other departments to offer solutions to an existing problem. More importantly though, they see opportunities to get their students involved in the projects and assist in community service, competitions, and research in order to solve a stated need. These projects and the opportunities for other students to assist in multidisciplinary, engineering design help the program meet ABET's Criterion 3(c-e):

(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems [8]

Likewise, we allow civil and mechanical engineering students to join projects sponsored by other departments, promoting more cross talk and coordination between all departments.

In addition to the publicity from Projects Day, the number of students attending the presentations has been a benefit. Some students who normally do not take engineering courses suddenly become curious and want to be part of a project in the future. Likewise, sophomore and junior civil and mechanical engineering majors who are unsure of what capstone project to pursue can see directly what others have done. They can read about the projects, look at static poster board displays which are required for each project, listen to the presentations, question the senior students who have worked on the projects, and query faculty advisors about the future of particular capstone projects.

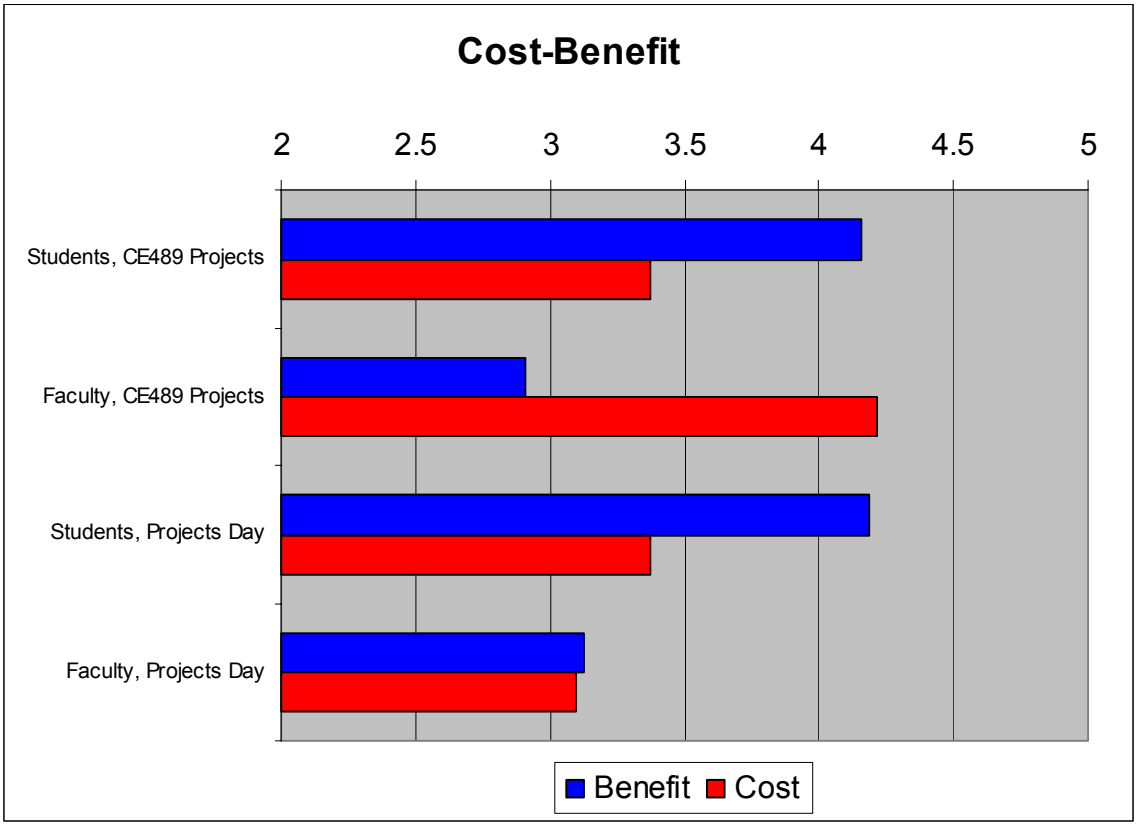

Figure 4. Cost-Benefit Comparison

In the same vein, clients invited to the presentations see new opportunities for projects. Their visit to Projects Day is more than a formality. They have a last chance to question the service provided by the students and provide feedback both formally and informally to students and faculty advisors. Many clients decide to continue projects or find new ones for future students when they see that their organization and the students mutually benefit from the experience. Through active participation during the project and by attending Projects Day, their contribution and support to the senior capstone experience gains credibility and meaning.

The seniors involved in these projects culminating with Projects Day see it as an opportunity to "strut their stuff" and demonstrate their products to the clients. Most students are eager to

present their work and welcome questions and challenges from the general audience – part of the ABET communication program outcome. The seniors are proud of their accomplishments and have even invited family members to attend their presentations. Projects Day provides a media opportunity for the department and the institution. Since the department has the largest participation in Projects Day, the Department of Civil and Mechanical Engineering has taken the lead in publishing articles about Projects Day and particular capstone designs in the local newspaper as well as the alumni magazine. These opportunities help the local community understand engineering and what our students can do. In addition, the publicity helps generate local community service projects for future students. The huge benefits do come with a cost – usually on the faculty side in terms of additional time requirements on top of existing teaching loads (Fig 4). However, educational research activities are one of the faculty benefits of many of these student projects.

V. Assessment

Client-based open-ended projects provide a wonderful opportunity for students to use all their skills to creatively solve a problem, while allowing the faculty another opportunity to assess whether the students have met ABET requirements. Reviewing the first five preferences for last year, 57 percent were service-based with 63 percent of the students listing a service-based project as their first choice. This past spring, 78 percent of the first five preferences were service-based with 70 percent of the students listing a service-based project as their first choice. In fact, some service-based projects have multiple teams of students trying to sell themselves to the faculty advisor as the team of choice. Last year one project had 3 teams vying for the opportunity to work on the project, while this past spring there were four projects with two students groups each wanting to work on the project. Each of the last two years, no service-based project went unfilled, while a few research-based projects were not completed.

We have assessed the effectiveness of our projects principally through the use of our institution's course-end feedback system. This system is administered entirely over the worldwide web and features a small number of USMA-standard survey questions, supplemented by department-specific and course-specific questions of our own choosing. Students respond to these questions using a scale of 1 (strongly disagree) to 5 (strongly agree). For the USMA-standard questions, this system allows us to compare our own students' survey responses to those of all other students at USMA. More importantly, the inclusion of course-specific questions allows us to survey our students about their achievement of specific course objectives.

On their course-end feedback, the students have been extremely supportive of completing open-ended projects, especially for a real client. Relevant data are provided in Figures 5-7. Fig 5 shows CE489 (client-based projects course listing) student responses to USMA-standard questions that relate specifically to the quality of instruction and student learning; nonetheless, we also believe these particular responses also reflect student satisfaction with the course described in this paper. Baseline values are averages for CE489 and USMA-wide responses. The USMA baseline responses have been extremely stable over time. Last year we had two projects with extremely low scores on the USMA questions for the first time. The advisors for these two projects were not able to provide the type of support the students felt was necessary. Earlier it was mentioned that there is a need for total faculty buy-in. In this case the faculty were focused

elsewhere. However, overall feedback is phenomenal considering that the students only meet at most once a week with the faculty advisor, i.e., an independent study course. Even though some of the students were not happy with the support from the advisor, the student's felt they accomplished (Fig. 6) the course objectives, lowest value being 4.0 (agree). The high average response—above 4.0 for these unique course objectives—reflects a high level of confidence in the course.

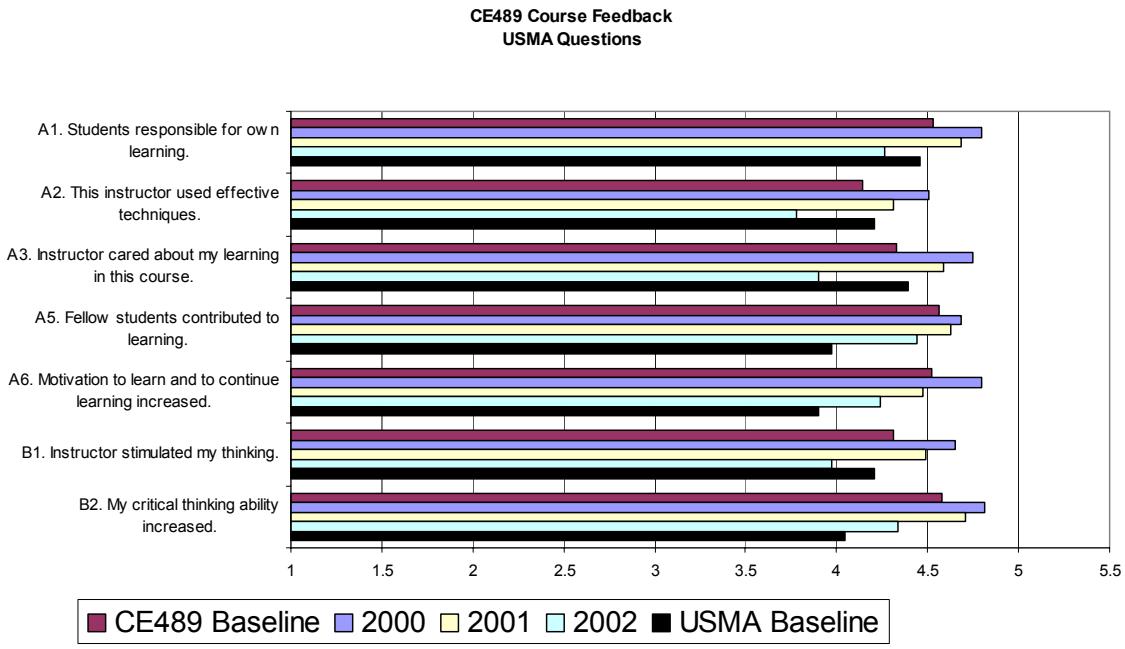

Figure 5. CE489 Course Feedback

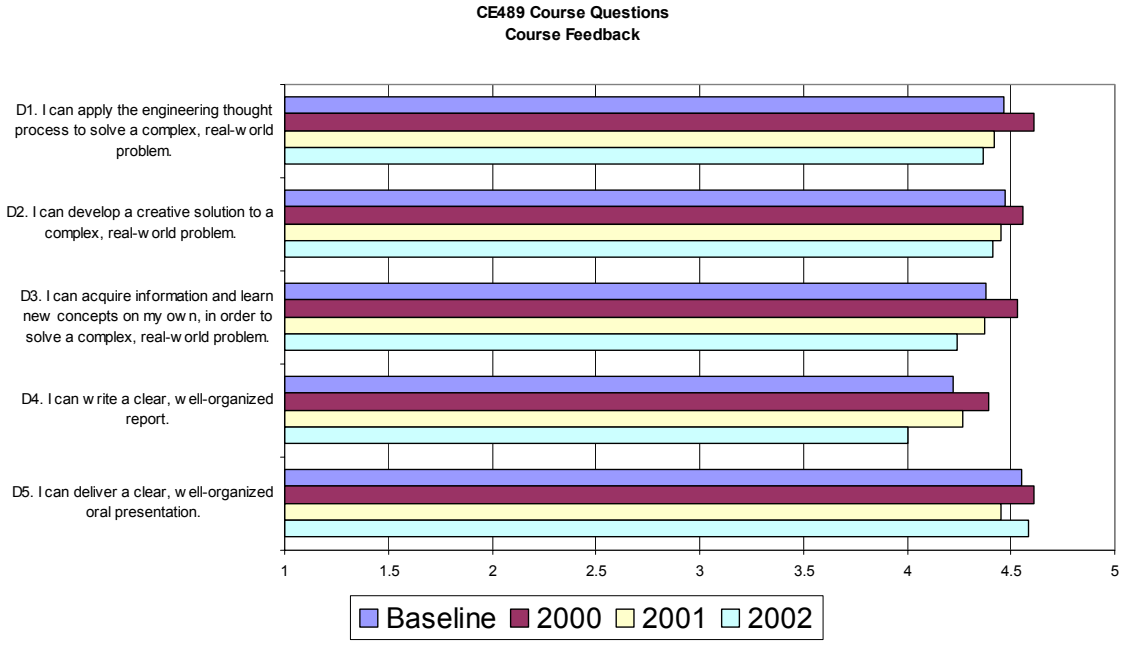

Figure 6. CE489 Course Specific Feedback

Comparison of 2002 feedback for the USMA questions against other senior civil engineering courses with the same general student population (Fig. 7; CE404 – Design of Steel Structures; CE483 – Design of Reinforced Concrete; CE491 – Advanced Structural Analysis), we see that this type of course is well received by the students even when considering how low the results were this particular year for CE489.

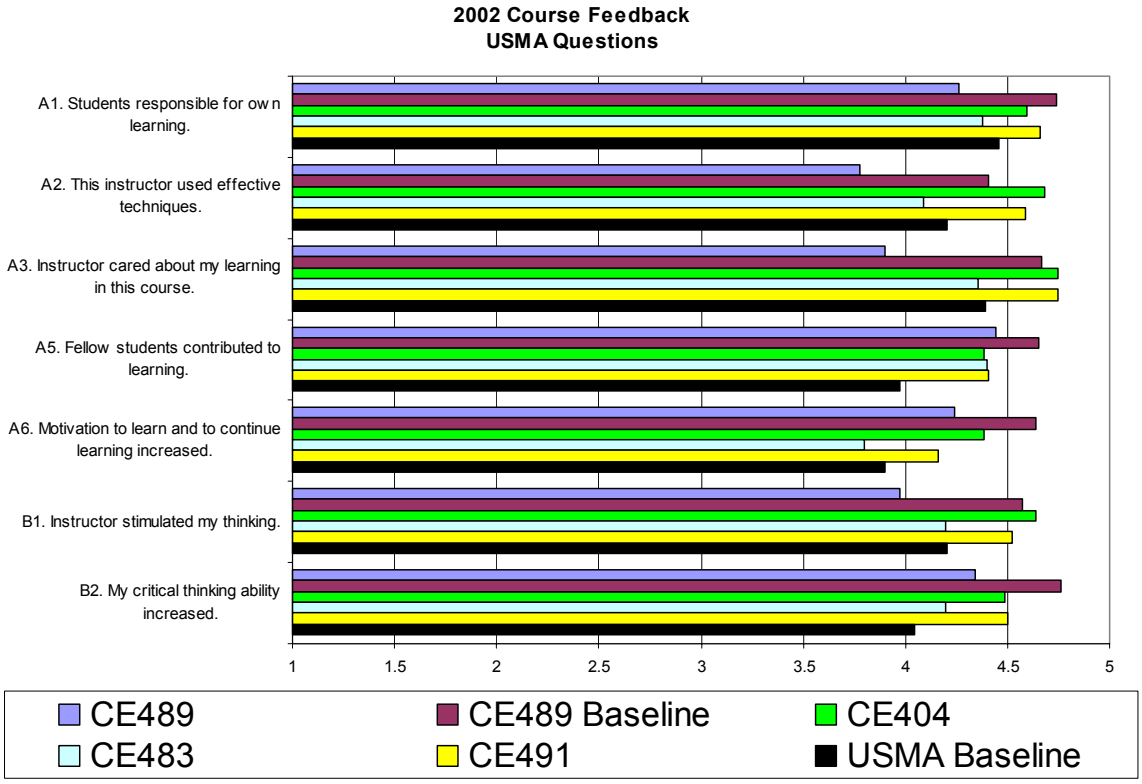

Figure 7. 2002 Course Feedback

In response to the "free text" question, "what did you learn form the course", a few of the student responses follow:

- I feel that this course was the perfect completion of my undergraduate education in civil engineering. I learned a great deal about what it takes to put together a project from ground zero to the preliminary design. It was perfectly tailored for what I need to learn.
- Students can make a difference.
- We have the knowledge to solve real-world problems.
- I know more than I thought I did about engineering and the problem solving methodology.
- I learned that there is much more to civil engineering than what I have learned in formal training.
- Working on an ambiguous project is more time consuming than other projects here.
- How to think outside of the box.
- That real-world problems require in-depth thinking and problem solving and that the skills I have learned earlier in my student career are actually applicable.

- My designs will work in real life and I am capable of designing something that works.
- A designer MUST take into consideration construtability.
- There are so many points in a project to get stopped or distracted. I learned how to anticipate them and react to them.
- I enjoyed learning how to "sell" an idea.

One student appropriately summarized the learning experience as follows:

"I learned more in this course than any other I have taken in the program."

Many other comments emphasized how much students valued being involved with real engineers, customers, and projects. Numerous students benefited from observing what other students were doing for their capstone projects and learned from them. Some students just observing Projects Day decided what discipline and capstone to pursue.

Projects Day itself provides an opportunity to assess the curriculum. ABET 2000 Criterion 3(g) states that graduates must have an ability to communicate effectively.[8] Clients receive a written product and a formal brief either at Projects Day or at the clients' business. Having spent at least a semester on a project, most design groups are so familiar with entire project that preparation for the presentation was really not a huge burden considering all the required information is in the completed report. Figure 6, Question D5 is an objective assessment measuring the students' confidence to present their capstone project.

Faculty advisors also received informal feedback from the clients. Most have reported enjoying working with the students and receiving a valuable product in return. Most of the sponsors volunteered again and many clients solicited the students' assistance in subsequent years, which is further evidence of their satisfaction with the program. In fact, the Popolopen Brook Bridge project was a multiple year project based on the quality of the work the first year. The excitement for the product displayed in Figure 1 drew in representatives from the New York Bridge Authority who were extremely impressed with the creativity displayed. The more permanent bridge, a cable-stayed suspension bridge, constructed by the New York Bridge Authority had its genesis in the work completed by the first student working on the bridge design.

VI. Conclusion

The students are providing solutions to real world problems for real clients. The reverse is also true, student involvement in solving the mix of problems and/or designing/building products stimulate the clients and sponsors to become heavily involved during the process. Increased client participation enhances not only the quality of the product, but the experience for the student and client. These semester-long projects are a great learning experience for all, including the faculty – something for everyone! The assessment shows that the students find the program demanding, but enjoyable and worthwhile because it forces them to push the boundaries of the their knowledge through initiative, self-study, perseverance, and creativity.

The Department of Civil and Mechanical Engineering's participation in USMA's Projects Day has been very positive for students, faculty, and clients. USMA promotes Projects Day as a

medium to communicate student capstone projects to peers, clients, and faculty. The Department uses Projects Day to seek multidisciplinary design opportunities, assess the curriculum and program effectiveness, and advertise the projects to prospective students. It allows engineering students to formally close out their project with the sponsors and faculty advisor at a substantially small effort to coordinate the event. Students graduate from the program with a better understanding of customer focused engineering and are better communicators.

Bibliography

1. Welch, R.W., "Client-Based Service Projects – A Mark of Excellence For Any Program," *Proceedings of the 2002 American Society for Engineering Education Zone I Conference*, American Society for Engineering Education, April 2002, West Point, Session C.
2. Welch, R.W., and Ressler, R.J., "Popolopen Brook Float Bridge Project - Integrating History, Community Service and Engineering Education," *Proceedings of the 2002 American Society for Engineering Education Annual Conference*, American Society for Engineering Education, June 2002, Session 2215.
3. Nakano, V.M., and Vander Schaaf, R.E., "Academics and Industry: A Win-Win Situation," The Lumber Co-Operator, Aug-Sep 2001, p.14.
4. Nakano, V.M., and Vander Schaaf, R.E., "Community Spirit," Woodwords, Aug 2001, p.52.
5. Conley, C.H., Leamy, M.J., Choi, Y.Y. and Hurst, H.C., "Finite Element Model Refinement Using Experimental Modal Analysis," Proceedings of the 72nd Shock & Vibration Symposium, Destin, FL, 12-16 November, 2001.
6. Conley, C.H., Choi, Y.Y., Hurst, H.C., Leamy, M.J., Gregory, F.H., and Gniazdowski, N.M., "Modeling of Blast-Loaded Structural Panels – Continued," Proceedings of the 9th Annual ARL/USMA Technical Symposium, Aberdeen Proving Ground, MD and West Point, NY, 5&7 November, 2001.
7. Dean's Policy and Operating Memorandum 02-30, Office of the Dean, United States Military Academy, West Point, New York, 2001.
8. URL: http://www.abet.org/images/Criteria/eac_criteria_b.pdf; Criteria for Accrediting Engineering Programs.

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