AC 2012-3868: CIVIL ENGINEERING CAPSTONE CONSULTANTS: FROM RFP TO REALITY

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Civil Engineering Capstone Consultants: from RFP to Reality

Introduction

Beginning in fall 2009, the senior capstone experience in Civil and Environmental Engineering at the University of Maine completed its evolution to a whole-department, writing intensive experience in a real world context. It provides the mechanism for students to transition from academics to the professional world, and is a great opportunity to apply coursework skills to real civil engineering projects.

Over the course of two semesters, seniors, working in teams of four to six, propose to solve a real engineering problem for an actual client, perform the engineering work as proposed, and finally present their designed solutions. To practice meeting the informational needs of different kinds of readers, students prepare two proposals: one for the Civil and Environmental Engineering faculty and one for their client. They also deliver oral and written progress reports for faculty advisors, course instructors, and clients. To support the process, the Civil Engineering and Engineering Communication Project (ECP) instructors provide formal instruction, active and frequent support and feedback on all aspects of their written, oral, and visual communication tasks. At the end of the spring semester, when the projects are completed, student teams present their problem analysis and recommendations to their client in the form of a detailed report and oral presentation. In a separate event, they also present to the Maine chapter of the American Society of Civil Engineers (ASCE) during a poster session,

Students receive four different grades from the four different instructors: Project Management (fall semester, 2 credits), Fall ECP (1 credit), Engineering Project Design (spring semester, 3 credits) and Spring ECP (1 credit). Neither course credits nor instructor workloads changed from earlier course sequences. Rather, existing courses were just adapted to the capstone experience.

This paper includes a literature review, description of the Capstone Consultants experience, advantages over previous capstone courses, specific management and organizational strategies, highlights from some actual projects, an assessment discussion and conclusion.

Literature review

Despite the considerable number of capstone-related papers that have been given or published[1], a review of literature revealed a few similar programs, but none with the same strategic combination of student-led projects and coordinated writing instruction. Many have industry partnerships, but only one other institution, Lawrence Technological University[2], has the students find and develop their own real service-learning projects. They report that "…students have repeatedly stated that they appreciate the opportunity to research and select the projects and

locations of their choice."[2] Similar to the University of Maine experience, they created a fictitious "Senior Design Venture Capital Fund" to solicit and evaluate proposals, and use poster presentations to review work. They have also included industry mentors more formally in their capstone process, with up to four project reviews through the two semesters. However, the University of Maine program is the only one that solicits two proposals: a faculty-reviewed capstone proposal that addresses the Department's capstone criteria, and a revised version that addresses client criteria.

In addition, Western Michigan University reports a proposal process, but in their case, industry sponsors develop project – specific RFPs in the fall semester that students respond to with written proposals.[3] In a somewhat similar fashion, students at California Polytechnic State University, San Luis Obispo write statements of qualification (SOQ) in the fall semester, followed by engineering work in the spring[4].

Capstone Consultants – the current capstone experience

"Capstone Consultants" is the fictitious consulting firm that actually consists of the departmental faculty and senior students. The department chairman is the president of the firm. The course instructors have the titles Development Manager, Engineering Manager and Technical Writing Manager. Given the management-intensive nature of these courses, these titles seem very appropriate. All the courses include elements of direct instruction by both the engineering and writing managers, but also include a great deal of engineering consulting-type management, targeted to a staff of new almost-engineers. Over the past few years, the typical class size has averaged about 60 students divided into 10-12 teams.

The process begins in the fall semester on the first day of class in Project Management, when the request for proposals (RFP) is distributed. Following sections on overview, background and current need, the scope section of the RFP simply asks for a comprehensive proposal to Department describing the proposed project. By about mid-semester, the students are required to have assembled their teams, found and evaluated potential projects, selected one, and written their capstone proposal. (See Appendix A for complete RFP). The departmental criteria for evaluating the proposals as suitable capstone projects are below.

Project-related criteria

1. The number and variety of different disciplines the project will involve, such as structures, geotechnical, environmental and water resources, transportation, sustainability, construction and public policy. (ABET[5] "multidisciplinary teams")
2. The real-world constraints such as economic, environmental, social, political, ethical, health and safety, constructability and sustainability.[5] In essence, the benefits to society from doing the project.

3. The amount of background information available to begin the project.
4. The commitment of the client to the project.
5. The uniqueness and overall excitement of the project.

Team-related criteria

6. The relationship(s) between team member(s) and the client.
7. The number and qualifications of team members with respect to the scope of work.
8. The apparent level of team commitment to the project.

The fifth one, uniqueness and overall excitement, attempts to give weight to projects that are different, potentially interesting to a wider public audience, or are particularly challenging. For example, one team did a project at Fenway Park in Boston, home of Red Sox baseball. With no prior contact, they approached the owners, described their capstone criteria, and eventually designed a restaurant addition to the stadium.

The students' proposal development is supported with lectures, classroom exercises, draft reviews and frequent meetings with each team. In Project Management, topics include teamwork, context of project management, scope development and work breakdown structure. In ECP, topics include resumes, progress reports and detailed section-by-section proposal development. Technical and rhetorical aspects are covered in depth. Instructors for both courses (Development Manager and Technical Writing Manager) work closely together and with the student teams, similar to typical consulting firm management practices.

Following departmental approval of their capstone proposals, the students then proceed to re-work them into comprehensive proposals to their actual clients. Again, the instructors / managers provide classroom exercises, draft reviews and team meetings to support and refine the proposals. In addition, each team is assigned a faculty advisor, who meets with the teams as necessary through the rest of the process. However, students are not limited to meeting with just the instructors and their advisor; they are welcome to seek advice from any faculty in the department, as well as practicing engineers in the industry. Over the course of the fall semester, the essential core of each proposal goes through three major drafts leading to a fourth final version. Each draft is reviewed in detail by both instructors, with written and oral feedback to each team. Shifting audience from the faculty to the client gives the students great practice in revision, but also foreshadows their transition from academics to the workplace. The results are comprehensive, near-professional grade proposals that frame the engineering work to be completed.

In the following spring semester, proposals are distributed to the clients confirming the nature and scope of the design work and the engineering work begins in earnest. In Engineering Project Design, the instructor is more of an Engineering Manager, and in the companion ECP course, the instructor is another Technical Writing Manager. During the design process, students evaluate

alternatives, consider regulatory, legal, ethical and social constraints, and estimate cost and schedule requirements. Students produce internal progress reports for Capstone Consultants, external progress reports for the clients, a poster presentation and finally a design report and presentation. The final reports themselves are considered to be conceptual designs – but have often been used by clients as decision making and/or marketing tools.

In the ECP lab the writing instructor provides support through a combination of class lectures, meetings with individual teams, and the posting to the course intranet folder of various resources. They are guided in the preparation not only of written documents culminating in the final engineering design report but also the design and presentation of project posters at the state ASCE meeting and the presentation of the projects to a panel of area professional engineers, who provide detailed feedback on both the engineering and the presentation aspects.

The writing instructor provides information and feedback on appropriate content for what are often non-technical readers, user-friendly organization, effective document design, and design of visuals. She covers the design of presentation slides and the techniques for successfully delivering effective presentations to different groups. Drafts of all documents are submitted to and reviewed by both the capstone instructor and the writing instructor, and the writing instructor works closely with the students in incorporating this feedback into their revisions. This aspect of instruction is usually carried out while the instructor and team members are sitting at a conference table so students and the instructor can discuss the pros and cons of various solutions to writing situations in a collaborative environment. The writing instructor also reviews draft designs for posters and outlines for oral presentations.

Finally, at the end of the spring semester copies of the completed engineering reports are distributed to area professional engineers, who review and assess them based on a single standard: Would you accept this as a report suitable to be issued under your company's name? The critiques of these practicing engineers, many of them graduates of the University of Maine themselves, effectively complete the transition from student to young engineer.

Student grades are based on writing and performance evaluations by the instructors in all four respective courses, although there is considerable discussion of grading within each semester. There are assignments that are specific to only one course, such as written exams in Project Management, and some assignments that are shared, such as the proposals. Teamwork and individual contributions are based on written evaluations by both peer and instructor at several points during each semester. Faculty advisors are not involved in grading, except on a voluntary basis of the final design report presentations.

Advantages over previous capstone courses

The major advantage of this two-semester coordinated approach is that it replaces a capstone course with a capstone experience. The engineering design project, including not only the final report but also various presentations and a poster session, is truly an educational capstone but it is also a transition from the somewhat structured, even passive life of a student to the more pro-active world of an engineer. Feedback from students, faculty, and outsiders involved in the process all indicate it is highly successful on these grounds.

In contrast to earlier iterations of the capstone experience, where all student teams worked on the same project, multiple projects make it much more interesting for both the students and the faculty. The fact that clients are all real communities and organizations challenges the students to be personally and professionally responsible. Each team develops its own connection to a community client, so they can't hide behind an instructor or another team on the same project. Given that realistic challenge, everyone in the Department has a stake in the students' success as well.

The expansion of the capstone experience to two semesters has provided many benefits as well. The fall semester proposal development process has been instrumental in improving the quality of the course and the students' engineering work. Not only do they experience the process of developing a comprehensive proposal, they really have time to determine what their project entails from an engineering perspective. They benefit from the extended time, multiple drafts and sequenced instruction that introduces proposal writing. Importantly, the definition of their scope of work improves dramatically through the semester. Between drafts, they learn from their clients as well. Each revision usually shows new and better information from site visits and questions brought up at draft reviews.

In their senior year, the capstone process slowly transitions the students from their academic environment to a professional world. They can apply many skills learned from coursework but quickly realize that their professional education is just beginning. Each project requires new technical knowledge, real context and skills. In contrast to their academic learning, organized and bounded by the faculty, the knowledge realm of the project is open-ended and primarily theirs. The roles are essentially reversed, making the student teams more knowledgeable about their project than the instructors. Faculty can advise and mentor but often don't have the specific knowledge required, causing the students to seek help from outside the University. This is an essential student-to-professional transition, consistent with industry management practices.

The capstone process also provides a great opportunity for students to build relevant experience toward their employment goals. By considering multiple projects before choosing the one they will tackle, each team has the flexibility to find and tailor a project to their interests. Such

experience is good for cover letters and job interviews, but also can provide a mechanism to give something back to their hometowns and local communities. Serving their communities can be a strong motivator, especially for such a people-serving profession.

Useful management and organizational strategies

Assembling the teams

Encouraged by the faculty, the student culture in Civil and Environmental Engineering has a strong component of teamwork. Beginning with the first semester Materials Laboratory course, students learn to work with their peers to solve problems in and out of the classroom. These working friend groups evolve through the four years; but often enough, new friends from the first semester become long-term relationships well past graduation.

Therefore, these well-established groups are given the chance to work on their capstone projects together, if they wish to do so. With some guidance and advice from the Project Management instructor, students are responsible for assembling their own teams. Students are told that teams do not have to include friends, that they should include a wide mix of discipline interests, and that the students with the highest GPA are not always the best capstone performers. In addition, the open-ended nature of capstone project work can be particularly stressful for the students, so they are advised to choose wisely and practically. To get them thinking about their differences, they are assigned to write resumes and take Meyers-Briggs Jung typology tests. Many friend groups still choose to work together because they are accustomed to working together and share at least somewhat compatible habits. After a couple of weeks, with resume assignments coming due, most of the class of 60 or so has self-selected into groups. At that point, any remaining un-grouped students are assembled into one or two groups by the Instructor - Manager. Sometimes smaller groups of three or less are broken up and distributed into other smaller groups. Contrary to conventional wisdom, these late-forming groups regularly perform well, sometimes better than the predominantly friend-based groups. The final result is usually 10-12 capstone groups of 4-6 students beginning their work toward a common goal.

Finding the projects

Based on a history of successful capstone projects and an institutional mission to serve the state of Maine, a number of clients approach the Department with projects every year. These are announced as available projects to the students in class, but ultimately the responsibility for finding an appropriate project rests with the student groups themselves. Guided by the RFP (Appendix A) and coached by the Instructor – Manager, the students are very good at finding projects. Using their many interests, backgrounds, hometown and industry connections, a typical group finds and evaluates at least three different projects before choosing a favorite to propose.

Sometimes students find great projects near home. One project, a pedestrian bridge across a river, included students from the two towns to be connected by the bridge.

ASCE Engineering Gala

Near the end of the second semester, students design and produce poster presentations for an "Engineering Gala" meeting with the state section of the American Society of Civil Engineers (ASCE). Organized jointly by the student and state ASCE chapters, it gives the capstone groups the opportunity to present their work to the professional engineering community. Friends and family are also invited. The presentations are judged by a panel of professionals, and the best three receive cash awards. For everyone, it's a celebration of the students' accomplishments, and a chance for the state ASCE to officially welcome students to their profession.

After the Engineering Gala, the capstone posters are displayed in the hallway of the Departmental building, as examples for current and prospective students. It's great to have fresh examples of the civil engineering profession for the visiting public as well.

Highlights from some actual projects

The projects themselves come from many areas of the civil and environmental engineering profession. There have been pedestrian bridges, transportation improvements, a parking garage, trails, salt sheds and a small hydroelectric project. In addition, there have been a number of buildings, including a restaurant on top of a ski mountain, fire stations, churches, an ice hockey rink and a multi-modal transportation facility. A number of water and wastewater projects have been undertaken through Engineers Without Borders (EWB) in Honduras. Appendix B contains brief project descriptions from the past two years.

For several years, capstone teams have worked on a wastewater treatment system for the community of Dulce Vivir in Dulce Nombre de Copán (Dulce Nombre), Honduras. With community input, the 2009-10 team researched and selected the two most desirable treatment system alternatives: a septic tank-leach field or septic tank- constructed wetland combination. In 2010-11, another team further designed and tested the feasibility of the two alternatives, selecting one, and finally creating a construction-ready design. The EWB chapter is now in the process of implementing the designs, and one more capstone team (2011-12) is working on an alternative design for a different part of the community.

There have been a number of different pedestrian and snowmobile bridge projects for communities around the state. One such span was 260 feet long across a river, providing access for snowmobiles and a groomer. In addition to the structural design, the team surveyed the site themselves, researched permits, designed foundations, addressed ice and scour problems. The

design result was a two-span steel girder bridge with a single pier in the river. From the professional review, one practicing engineer wrote "very thoughtful solution. This team faced unique challenges, completed independent research of standards, [and] developed a solution that showed good engineering judgment."

Another interesting river project was feasibility study of a micro-hydroelectric project at the site of an old sawmill in Vermont. The only remnants of the old sawmill were the foundation and some remains of the old intake, penstock, and tailrace. The project included the design of a diversion wall, the redesign of the intake, penstock, turbine drop area, and the tailrace. Economic and environmental aspects as well as constructability and overall sustainability were also considered. From the professional review, one practicing engineer wrote "best overall design, well thought out, all via a Skype connection to the client in Vermont."

One particularly challenging building project was a two-story restaurant with a wrap-around deck on top of a mountain at Sunday River ski center in Newry, Maine. The team had to learn basic architecture, analyze the structure, design key structural members, design a water and wastewater system, analyze rock samples from the site location, and compare costs between the different design options. In addition to the extreme structural loading aspects on top of a mountain, the water and wastewater system designs were particularly daunting because of the large elevation differences.

Assessment discussion

As a result of the final changes with the fall course in Project Management, student course evaluation ratings went up substantially. Averaging responses from the previous four years and comparing to the last two in the new system, the question "How would you rate the subject matter of this course?" improved 18%, and the question "What was your overall rating of this course?" improved 25%. Over the same time period, student evaluations for the subject matter question stayed the same, but the overall rating question improved 7%. Comparing the average College of Engineering evaluation result over the same time period showed overall improvement of 2% and 4%, respectively.

An online voluntary survey of recent graduates was conducted to gauge student opinion on the capstone experience. Approximately 50% of the former students polled answered the survey, for a total of 23 individual respondents. The survey asked for responses scaled from strongly disagree (1) to strongly agree (5). Table 1 contains the results of three team and project selection questions, and shows strong support for the current system. Table 2 contains the results of the proposal process questions and also shows good agreement from the students. Table 3 contains the results of the mentorship and motivation questions and again shows strong agreement. According to Marin et.al.[6], major parts of a successful capstone experience are successful

instructor mentorship, student ownership of their design projects, creative tension experience with the project goals, and the opportunity to fail as well as succeed. Questions 8-11 clearly indicate success.

TABLE 1: Results of recent graduate survey: Team and Project Selection

Question (statement)	Agree (%)	Strongly Agree (%)	Rating Average
1. It was a good experience to find and select our capstone project.	40%	50%	4.40
2. Assembling our own capstone team was better than being assigned by the instructor.	25%	70%	4.65
3. Overall, the project and team selection process was optimal.	45%	40%	4.25

TABLE 2: Results of recent graduate survey: Proposal Process

Question (statement)	Agree (%)	Strongly Agree (%)	Rating Average
4. Writing the proposal to the faculty helped our team understand the capstone process.	55%	35%	4.25
5. Writing the proposal to the client helped our team visualize and define the final project.	50%	40%	4.30
6. The proposal draft review process was beneficial.	35%	50%	4.30
7. Overall, the proposal phase of the capstone was optimal.	50%	35%	4.20

TABLE 3: Results of recent graduate survey: Mentorship and Motivation

Question (statement)	Agree (%)	Strongly Agree (%)	Rating Average
8. Our capstone team felt that we owned the project more than the University.	25%	65%	4.55
9. Our capstone design experience was driven by the proposal.	50%	30%	4.10
10. Our capstone team felt that we were given the opportunity to succeed or fail on our own.	25%	75%	4.75
11. Overall, our capstone team felt that we were ultimately in charge of our project.	10%	90%	4.90

In addition to student assessments, practicing engineers who have reviewed presentations and reports have been impressed. For example, comments have included "matching what is done in real life," "very well done, detailed in all areas," "clear, thorough report, nice details… felt complete," and "interesting design concept – a good attempt."

One recent graduate wrote to praise for the program, particularly the writing process. Pellerin[8], a May 2011 graduate, writes about his current job experience and the importance of writing skills in an open letter to current seniors:

> The design-build process requires the submission of a technical proposal much like the capstone projects you are working on. It has become evident that coming up with a concise and clear proposal is crucial to winning these design build jobs since a lot of the designs and cost estimates can be similar between competing teams. Expressing your research, design and proposed methods of construction in a clear and concise way are equally as important as the design itself. I have found that the technical writing skills I developed through the ECP program (especially senior year) have added to my value as a young engineer. I have actually had the opportunity to give advice to some of my superiors.

With regard to ABET[5] accreditation, the capstone experience addresses nearly all the criteria from program outcomes 3 a-k, below. On a scale of 1 (strongly disagree) to 5 (strongly agree), students rated them consistently between 4 (agree) and 5 (strongly agree) for the past two years that data was available.

(a) an ability to apply knowledge of mathematics, science, and engineering: **not evaluated**

(b) an ability to design and conduct experiments, as well as to analyze and interpret data: **not evaluated**
(c) an ability to design a system, component, or process to meet desired needs: **spring 4.39**
(d) an ability to function on multi-disciplinary teams: **fall 4.59, spring 4.32**
(e) an ability to identify, formulate, and solve engineering problems: **spring 4.27**
(f) an understanding of professional and ethical responsibility: **spring 4.40**
(g) an ability to communicate effectively: **fall 4.56, spring 4.39**
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context: **spring 4.22**
(i) a recognition of the need for, and an ability to engage in life-long learning: **spring 4.12**
(j) a knowledge of contemporary issues: **fall 4.52, spring 4.04**
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: **spring 4.35**

Conclusion

In summary, the two-semester capstone experience is working well. For the students, it provides a transition from academic to professional life. For the instructors, it is a real management exercise. Overall, Capstone Consultants has been a successful modification of existing courses but could still use some improvement.

Preparing comprehensive, detailed written reviews of writing drafts is very time consuming, as are conferences with individual teams to personally discuss the reviews. In a conference week, usually at least four times a semester, the instructors schedule and meet with a dozen teams, often for as much as an hour with each. Mentally, it can be challenging to keep all the projects separate, while providing timely writing and engineering recommendations for each.

Student outcomes assessment could certainly use some additional attention as well. Although the technical writing instructors have developed some, comprehensive rubrics should be developed and refined for grading and student feedback. The practicing engineers do a great job of evaluating design reports and presentations, but they could perform even better with a more substantial evaluation framework.

Although the ASCE Body of Knowledge[7] (BOK) is discussed in the Project Management course, it isn't specifically used in the capstone experience. It could potentially be used to develop better evaluation rubrics as well as to better define the outcomes assessment process.

Finally, the primary intent of this paper is to share the unique, multi-project capstone project experience in Civil and Environmental Engineering at the University of Maine. The authors hope some of the approaches, advantages and management strategies can be useful for other institutions.

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Appendix A: The RFP

Request for Proposals: Capstone Projects, fall 2011

Overview

Student design teams will be established to identify and develop a proposal for a capstone project for CIE 411, Engineering Project Design, in the spring semester 2012. The first version of the proposal will be addressed to the Civil and Environmental Engineering Department Faculty. Following approval, it will be refocused and sent to the clients themselves.

Background information

The civil engineering capstone project provides a two-semester experience for students to transition from their academic experience to a professional experience. It is a great opportunity to apply the many skills learned through coursework to a real civil engineering project. Teams of four to six students are self-selected to provide an appropriate range of specialty interests, such as geotechnical, environmental, water resources, structures, transportation and construction. The final product of the fall semester will be a comprehensive proposal to the client from each team. In the spring semester, the engineering and design work as proposed will be performed, and the final report to the client will be due at the end of the semester. Regardless of the project scope, the final engineering report will be expected to address the following broad issues: economic, environmental, social, political, ethical, health and safety, constructability and sustainability, in addition to the specific technical engineering work.

Current need

We are currently looking for capstone project ideas to investigate and develop. Each project should address a real engineering need for a community or non-profit organization. Most projects in the past have been in Maine, but they have also included Fenway Park, a Native American hydroelectric project in New Brunswick and an Engineers Without Borders project in Honduras. Posters from recent projects are posted in the 3rd floor Boardman hallway.

This is a great opportunity for students to give something back to their hometowns and communities. It is also a great opportunity for students to build relevant experience toward their employment goals. Such experience is good for cover letters and job interviews.

Based on the department's reputation and contacts, a number of projects are already available, but the final responsibility for finding an appropriate project rests with the students.

Scope

Provide a comprehensive proposal to the Civil & Environmental Engineering Department describing the proposed project. Address the proposal to William Manion, Development Manager.

Timeline

- September 2011: RFP is distributed
- Friday, 30 September 2011: First progress report due
- Friday, 14 October 2011: Proposal due to Capstone Consultants
- Last week of classes, 6 & 8 December 2011: Proposal presentations in class
- Last day of classes, 9 December 2011: Final proposal due to client
- January - May 2012: Project engineering is performed and presented in CIE 411.

Criteria for evaluating capstone proposals

Project-related criteria

1. The number and variety of different disciplines the project will involve, such as structures, geotechnical, environmental and water resources, transportation, sustainability, construction and public policy. (*ABET "multidisciplinary teams")
2. The realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability and sustainability. (*ABET) In essence, the benefits to society from doing the project.
3. The amount of background information available to begin the project.
4. The commitment of the client to the project.
5. The uniqueness and overall excitement of the project.

Team-related criteria

6. The relationship(s) between team member(s) and the client.
7. The number and qualifications of team members with respect to the scope of work.
8. The apparent level of team commitment to the project.

Contact information

(omitted for review)

*Accreditation Board for Engineering and Technology (http://www.abet.org/)[5]

Appendix B: List of projects from the past two years

1. To design a snowmobile/pedestrian bridge over the B Stream in Houlton, ME, for the Meduxnekeag Ramblers Snowmobile Club similar to the nearby Aroostook Riders Snowmobile Club Bridge. The bridge needed to accommodate one-way snowmobile traffic of up to 700-1000 snowmobiles per day on peak days and the bridge deck had to be above the 100-year flood level.

2. To design a ski lodge for the Fryeburg Academy Nordic Ski Team and an additional parking lot for the Stark's Hill Nordic Ski Area. The ski lodge had to provide a place for the ski team to prepare for ski meets and for officials and coaches to meet during races. The parking lot needed to accommodate buses and cars that come to the events.

3. To design replacement structures and support systems for University Park, specifically: a two-story building with multiple units; site layout for multiple buildings, including a community center; an improved traffic pattern; a water management plan. Our objectives include achieving LEED certification and a 50-year life expectancy.

4. To design a multipurpose athletic complex at Old Town High School, including an artificial turf field, a 400m track, 2500+ overall seating for spectators, a double-sided press box and an addition to the current parking lot. We used commercial prefabricated grandstands that met our specifications but designed all other elements of the project.

5. To design replacement pedestrian footbridge for the existing Peterbilt Bridge in Township 3 Indian Purchase near Millinocket, Maine. The project included researching applicable codes and investigating materials, as well as actually designing the structure and footings.

6. To design two stream crossing at Black Brook and Wadleigh Brook in Baxter State Park to facilitate healthy fish passage. We designed a culvert at Black Brook and a bridge at Wadleigh Brook. Our criteria included material cost, constructability, and life cycle analysis.

7. To design a replacement firehouse, including the layout, foundation and structural system; a septic system, including specifications for a septic tank and a leach field design; a parking lot with proper runoff ditches and, if needed, a retention pond. We also investigated relevant permits.

8. To design a composting latrine, greywater filtration system, and storage shed with access road in Dulce Vivir Honduras. Because of the location and the do-it-yourself nature of

this Engineers Without Borders project, our criteria included cost-effectiveness, efficiency, and especially builder- and user friendliness.

9. To design a recreational area for the City of Old Town consisting of a parking lot, lean-tos for overnight camping, a pavilion, walking trails, a self-composting restroom, and a dock. We also investigated necessary permitting, especially in regard to the Penobscot Indian Nation concerns.

10. To assess the relative feasibility of three solutions to the problem of the failing North Wharf at Bath Iron Works and design the solution we thought most feasible. BIW presented us with three options: (1) removing the wharf and enlarging the bulkhead (2) simply securing the existing wharf so that it is safe; (3) completely redesigning the wharf. Our criteria for feasibility include cost, sustainability, and functionality.

11. To design a new combination fire station and town office for the town of Farmingdale, including a floor plan for the structure; two distinct parking areas, including handicapped parking; and a site drainage system.

12. To design a two-story restaurant serve 100 people atop Jordan Peak and facing the Mount Washington summit while meeting Americans with Disabilities Act requirements and providing space for the ski patrol and storage on one of the floors; to design a system to transport water and waste up and down the mountain.

13. To design a durable, relatively inexpensive shelter for salt and sand supplies with easy site access for snowplows and other equipment; to design run-off management system to avoid salt contamination of nearby public-water wells.

14. To design a church building containing large and small worship spaces, a large meeting space, a kitchen and service spaces; to design a parking lot with handicapped accessibility; to make the building as energy efficient as possible, with the goal of LEED silver certification.

15. To create a cost-efficient, sustainable, environmentally sound plan to manage water flow in the Strawberry hill area so as to avoid flooding of streets and residences.

16. To design a three-level parking structure in the present Dunn/Corbett parking lots that alleviates parking problems caused by special events in that area of the campus; to develop a traffic plan that addresses the increased traffic the new structure will generate.

17. To design a handicap-accessible pedestrian-snowmobile bridge to connect the towns of Hollis and Buxton using, if possible, existing railroad abutments; to address issues related to limited access to the site for construction equipment; to research and work within applicable environmental regulations.

18. To design a more effective culvert system under Slab City Road that will be inexpensive to install, require minimal maintenance, and enhance the passage of native salmon through Black Brook; to take into account possible modifications to Slab City Road, which passes over the culvert.

19. To design a utility-terrain vehicle (UTV) trail and bridge from the Old Town Canoe facility to the Penobscot River to facilitate transporting canoes to the river for product testing and recreational activities; to create plans for a waterfront area for loading-unloading canoes from the UTV and launching them into the river.

20. To design a new, larger, more efficient firehouse for the town; to develop a water management system both within the building and on the site; to create a parking lot for the safe movement of fire trucks and other vehicles.

21. To design three ADA-compliant pedestrian bridges that are visually/aesthetically related yet functionally suited to three distinct locations; where feasible, to use advanced construction materials to prolong the life of the structures.

22. To design a pedestrian-snowmobile-ATV bridge, including foundation, abutments, and the bridge structure itself; to investigate applicable environmental issues and permitting.

23. To develop two designs for an amphitheater (seating and stage) that will fit "organically" into the site; to address environmental conditions on a site that floods frequently; to investigate the feasibility of solar lighting and natural sound barriers (trees and bushes).