AC 2007-2846: BRIDGING BEAR HOLLOW: A SERVICE LEARNING CAPSTONE DESIGN

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Abstract:
Service learning is loosely defined as a structured activity that extends learning beyond the boundaries of the classroom and promotes that learning through active participation in service experiences. Service learning is uniquely distinct from pure volunteer or community service in that learners are afforded the opportunity to apply previously acquired knowledge and skills to the solution of real life problems for the betterment of both the community and themselves. In theory, the model of service learning is an ideal vehicle for simultaneously satisfying the culminating design experience required by ABET Criterion 4, producing a product for the betterment of the community, promoting university goodwill and instilling an ethic of public service in the student. In practice, however, poor project selection and poor conceptual development of service learning activities will negate any of the positive attributes listed above. In fact, the difficulty in creating meaningful service learning projects for the capstone design courses has limited their use. Fewer than 30% of the 477 campuses that responded to the Campus Compact survey on service learning have used service learning projects as culminating design experiences in all disciplines. The statistics for engineering disciplines is even lower. In light of the proposed "Body of Knowledge" for civil engineering programs the use of well crafted service learning activities should increase significantly. This paper describes the attributes of a service learning activity, used as the senior culminating design experience, which resulted in the successful design and construction of a timber bridge for a non-profit educational organization located about 45 miles from campus. The bulk of the paper focuses on a discussion of the planning and organizational activities required to meet logistical, environmental and permitting challenges faced by students. In addition the tasking, scheduling, design, monitoring and assessment activities undertaken to insure the successful completion of the project are discussed. Assessment data is presented to establish the successfulness of the project in integrating previous knowledge to the design of a system, dealing with real life constraints, engineer-client relations, and instilling an increased commitment to community or public service in the future.

Introduction

According to some researchers, service learning has its roots in the Morrell Act of 1862 which created land grant colleges to promote "…practical education of the industrial classes in the several pursuits and professions in life." [1]. The reasoning is that land grant institutions would create a core of citizens with an education rich in agriculture and mechanics who would further the goals of the Nation. However, service-learning as we think of it today did not really start to evolve until the 1960s when VISTA (Volunteers in Service to America) was created as part of President Johnson's War on Poverty program. It was VISTA, the Peace Corps and the National Teachers Corps that really started to focus on bringing a unique skill set to volunteerism. In 1990 Congress passed the National and Community Service Act which authorized grants to schools to support service learning. It was after this legislation that the current definition of service learning evolved. A broad definition of service learning which is nearly universally accepted by all and is posted at the National Service-Learning website is as follows: "Service-learning is a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience and, teach civic responsibility, and strengthen communities." [2]. More practically, in engineering education the definition of service learning could be modified to include the fact that students should be required to bring specific and unique knowledge, gained in earlier coursework, to bear on a problem that might otherwise not be solved. The application of knowledge and service should benefit both the community and service provider [3].

In theory, the model of service learning should be an ideal vehicle for simultaneously satisfying the culminating design experience required by ABET Criterion 4, producing a product for the betterment of the community, promoting university goodwill and, instilling an ethic of public service in the student. In practice, however, poor project selection and poor conceptual development of service learning activities will negate any of the positive attributes listed above. In fact, the difficulty in creating meaningful service learning projects for the capstone design courses has limited their use. The Campus Compact, an organization that monitors the service activities on college campuses, estimates that over $4.45 billion of service is contributed by students at member schools each year. Yet, at the same time, fewer than 30% of the 477 campuses that responded to the Campus Compact survey on service learning [4] have used service learning projects as a culminating design experience in all disciplines. The statistic for engineering disciplines is even lower. The results of this survey points to the fact that the engineering education community has a lot of room to grow in the service-learning arena. We in the engineering community should not try to reinvent the wheel when it comes to service learning but should take advantage of the pioneering work reported by our colleagues in the social sciences. For example, Geiger and others have created learning tool kits or compendiums of best practices to help faculty get started in service learning activities, [5]. Listed below are a few key elements for ensuring a successful service learning experience which were gleaned from a number of references;

1. Set specific educational objectives and determine how the service learning activity fits within the curriculum. Devise assessment rubrics to determine if the goals are being met.

2. Assess the needs and resources of your community and school and form partnerships within the community

3 When selecting a project determine how all partners will work together to achieve the goals. Insure the necessary funding and resources before planning the project.

4. Plan early and in detail. Establish a reasonable timetable, develop a budget and assign tasks.

5. Actively manage the project insuring that timelines are met and assess the effectiveness of activities.

6. Incorporate reflection and celebration. Students need to think about how they are contributing to service and how that service is contributing to their learning. All parties need recognition at the end of the project.

Capstone Designs

A portion of Criterion 4c from the Criteria for Accrediting Engineering Programs, published by the Accreditation Board for Engineering and Technology (ABET), requires students to be prepared for engineering practice "…through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework…". This culminating design experience has been labeled by many as the "Capstone Design." ABET does not prescribe the mechanics of how this experience is to be administered. It instead allows the individual institution the latitude to define what a culminating experience is and how that experience meshes with its curriculum. As a result, a wide variety of culminating experiences exist at various institutions. Welch, [6] reports the use of one-semester design-build projects as an excellent venue to satisfy criterion 4. While Jenkins, et.al.,[7] describe a two-semester sequenced capstone experience that requires the technical work to be performed in the first semester, while professional issues are dealt with in the second semester. Farr, [8] advocates using project based design experiences where the student must prepare a real product for a real client. Still others, like Kolar [9], and Wood et.al.,[10] suggest an integrated and systematic approach to design which spans the entire four year curriculum. In the Civil Engineering program at the University of Arkansas the culminating design experience prescribed in Criteria 4 has been satisfied with a course titled Senior Design, CVEG 4494, a four credit hour, single semester course dedicated to a culminating design experience that requires the application of design principles learned in previous course work.

Senior Design, CVEG 4494, was introduced to the Civil Engineering curriculum in 1989. Its introduction was a direct result of the program self study prepared for the 1990 ABET accreditation visit to the department. Through that self study the faculty recognized that the extant culminating experience did not fully meet the requirements of Criterion 4. Senior Design replaced a course called Senior Seminar which was dedicated to addressing professional issues in the curriculum. The original goal of Senior Design was to have students engage in a significant design project (sub-division, water treatment plant, bridge, office building, etc.) in order create a technically correct design accompanied by a set of plans and specifications suitable for use as bid documents. In addition, many of the professional issues topics, included in the Senior Seminar course, were to be addressed. Tenure track and adjunct faculty have taught Senior Design, both individually and in combination, at various times during its 17 year history. The prerequisites for CVEG 4494 are Basic Soil Mechanics, CVEG 3133, Introduction to Environmental Engineering, CVEG 3243, Transportation Engineering, CVEG 3413 and either Concrete Design, CVEG 4303 or Steel Design, CVEG 4313. Senior Design has two three-hour meetings per week, which are a combination of lecture and design studio. This course has routinely been rated by students over its entire 17 year history as one needing improvement. Common complaints like: "more time and effort are focused on making pretty plans than on real design", no real data is available for design", "our group was not technically prepared for the design", or "the scope of the design was too big for one semester" were repeated every semester. At the same time the faculty saw the course as one without ownership. Normally, the faculty member assigned to the course viewed it as a teaching overload or as a service course which required significant preparation and did not contribute materially to the generation of potential graduate students. In addition, it detracted from research. In short, the recurring problem with this course, independent of who taught it was that students did not like it. They saw it as an exercise in learning how to use CAD to produce pretty construction drawings rather than a course that would improve their ability to address the many tasks, both technical and professional, that must be completed to produce a quality design and communicate with a client.

Service Learning

In an attempt to overcome some of shortcomings of previous offerings of the senior design course the concept of using service-learning was viewed as a vehicle to integrate the best concepts of a capstone design course, as cited by others, and to instill a sense of ownership in the subsequent work that would result from the design. In particular the goals of this service learning activity were to foster a sense of commitment and service among the students, allow the students to interface with disparate groups, get the students engaged within the community, satisfy many of the ABET Criterion 3 outcomes and to satisfy ABET Criterion 4-c.

One of the most critical tasks associated with service learning is selecting an appropriate project with the correct magnitude and technical complexity that will insure success in the achievement of the outcomes of the program. Fortunately this task did not turn out to be a serious issue at the University of Arkansas. In the early summer of 2005 a local volunteer organization, called the AT&T Pioneers, approached the civil engineering department to get some assistance in designing a bridge that could be built in a primitive environment by semi-skilled volunteer labor. This project was being undertaken to meet a stated need of the Ozark Natural Science Center, (ONSC). The ONSC is a non-profit education facility dedicated to providing innovative field science programs for all learners. Its stated mission is to enhance the appreciation, and stewardship of the Ozark Natural Environment. One of its major functions is to provide a variety of nature visits to local area schools. The center is located within a 486 acre tract of land in Madison County, AR, known as Bear Hollow. This parcel of land is controlled by the Arkansas Natural Heritage Commission and has remained completely primitive. In fact, the management of the land is so dedicated to maintaining the natural environment that domestic animals are prohibited from being taken into the area. Central to the natural science activities of the ONSC are nature walks which require students to cross Bear Hollow Creek. Normally this creek has a very low flow as illustrated in Fig 1, and is easily negotiated by students. However, during certain times of the year water can rise quickly making the creek a hazard to hikers and presents the possibility of stranding them on the far side.

The initial request from the AT&T Pioneers was only for a design for some type of crossing over Bear Hollow Creek. However, the faculty saw this as an opportunity for students in Senior Design to get involved in all facets of the conceptualization, design and construction of this project. It had all the earmarks of a superb service learning project.

The Project

The ONSC needed and all weather, emergency crossing across Bear Hollow Creek that would be economical, blend into the environment, be constructible with volunteer labor in a primitive environment and satisfy code requirements. The faculty felt the students in senior design possessed all the requisite skills to tackle this project from beginning to end and the students welcomed the challenge to undertake a real project with real constraints that would be actually built.

The first step in the project was to get all parties; the community volunteers, the 15 students in the Senior Design class, the staff and board of direction of the ONSC and the CE faculty together on site to establish the needs, timing, funding and resources available to complete the project.

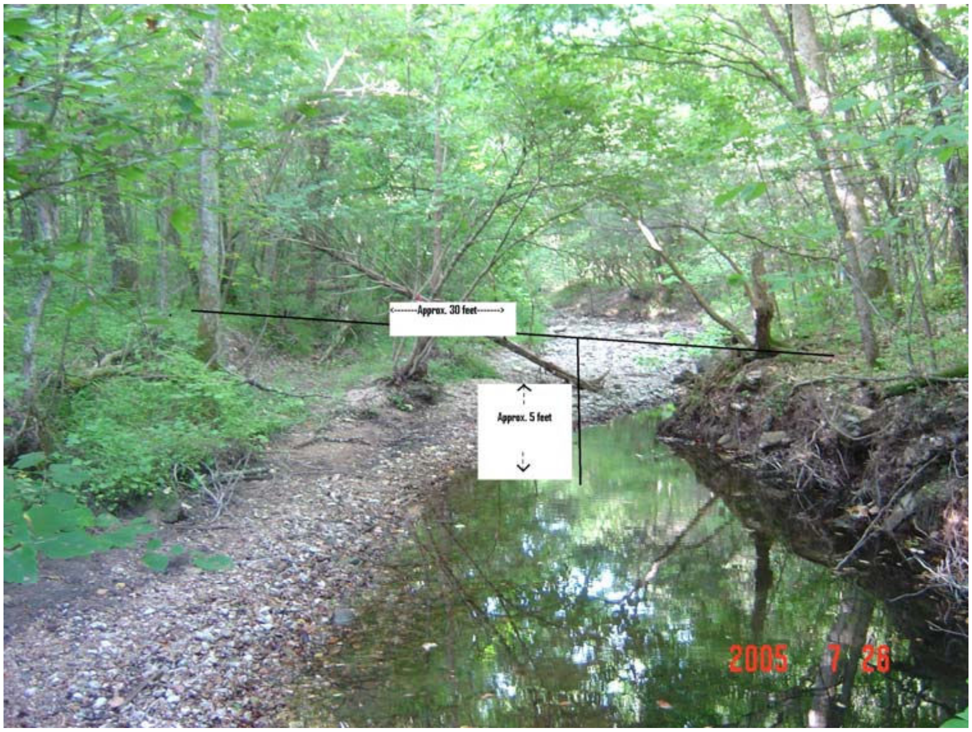


Figure 1. Proposed bridge crossing location across Bear Hollow Creek.

Prior to this meeting the students organized into specialty groups (water resources, geotechnical, structural, construction management, permits and regulations, etc.) and compiled a list of questions that they needed to ask both the ONSC representatives and the Pioneers. They also established a rudimentary time line that needed to be met in order for the design and construction to be completed before the end of the semester. As a result of this first meeting the students learned that cash to support the project was limited and that many “in-kind” donations would be solicited by the Pioneers to get construction materials. The use of heavy equipment at the job site would be prohibited, i.e. everything had to be carried to the site and only hand tools could be used in construction, the crossing had to meet all codes and standards and had to be approved by the History and Heritage Commission. Initially, the staff of the ONSC wanted to have the capability of getting the 4-wheel ATV shown in Fig. 2a across the creek on what ever type of structure was planned. However, once the students acknowledged that this could be done the requirement escalated to getting the tractor shown in Fig 2b across.

Through the questioning process it became apparent that the client, (ONSC), wanted some type of bridge for the crossing. Any type of low water crossing or series of culverts was considered to be unacceptable, both from an aesthetics standpoint and a regulatory standpoint. Armed with the constraints and criteria gained form the on-site visit the students organized into four design teams in order to create independent concept designs for a crossing that would support three potential loadings; pedestrian only, ATV traffic, and the construction tractor. An estimated cost and rough

a b

Figure 2. a. Four wheel ATV emergency vehicle (1670 lb.) b. Small construction tractor with box blade and front end loader (5700 lb).

bill of materials was created for each concept design. Two weeks after the initial visit each design team had prepared a formal presentation to brief the members of the ONSC staff and board of direction on their concept. The briefing was intended to outline the advantages and disadvantages of each proposal. Based on the information provide in the formal student presentations, the ONSC representatives elected to combine elements from two of the concept designs to satisfy both aesthetics and cost issues. As a result of the board's cognizance of the cost and potential liability issues pointed out by the students for bridges that could support vehicular traffic, the board decided that the final design should not allow the conveyance of any type of vehicular traffic. However, they still wanted it wide enough to get a Stokes Litter across with four litter bearers.

Once the decision was made on the concept of the bridge, the students revisited the site to gather more specific information on topography and subsurface conditions. In addition, they surveyed the resources and materials that were potentially available at the ONSC for the construction of the bridge. A complete topographic survey was conducted along both sides of the streambed for a distance of 500 m above and below the proposed crossing using a total station. Based on the data collected from the survey a complete hydrologic analysis was conducted to determine the extent of flooding for a 20 year design storm. This information was in turn used to establish the elevation of the bridge deck and the locations for abutments. Recognizing that all of the structural elements would have to be carried into the site and assembled in place, a timber Warren Truss was selected as the bridge superstructure. No individual truss member was longer than 16 feet (lower cord elements) and all members were constructed of treated 2x6 dimensioned lumber to insure their portability and longevity of the structure. All connections were to be bolted.

While the students demonstrated that they could conduct topographic surveys, perform hydrologic and hydraulic analyses, assess ground conditions and design foundation they were weak in structural design skills. Early in the structural design process it became clear that all of the students lacked the requisite knowledge to correctly model the structure and to design its connections. To remedy this shortcoming, "just in time learning" techniques were used to communicate the necessary elements of structural analysis and timber design that the students were lacking. Since the final design and drawings had to be stamped by a professional engineer student work was checked carefully for accuracy. At the conclusion of the preliminary design stage a second briefing was conducted to give the ONSC representatives and the Pioneers a better idea of the final look of the bridge and an idea of the materials and labor requirements to get it constructed. Students used the physical models illustrated in Fig. 3, in addition to their PowerPoint ® presentation, to communicate the intricacies of the design and some of the details of construction. A detailed bill of materials was developed and decisions were made about which elements would be purchased outright and what items would come from in-kind donations. A rough division of labor was also established. Prior to the construction phase the Pioneers were to canvas local merchants to get in-kind donation of cement, connection hardware and lumber. During the construction phase the students were to complete the bridge foundations and structural elements of the superstructure, the ONSC staff and the Pioneers would then deck the bridge and install the safety cables in the lattice work of the trusses.

In response to modifications requested in the final briefing the 100 percent design and construction drawings were completed in late October and submitted to the Arkansas History and Heritage Commission for approval. It was expected (by the students) that the approval would be immediate. However, that was not the case and the construction phase was delayed by nearly

Figure 3. Student created physical models illustrating alternatives for the approaches and connection details of the superstructure of the proposed bridge.

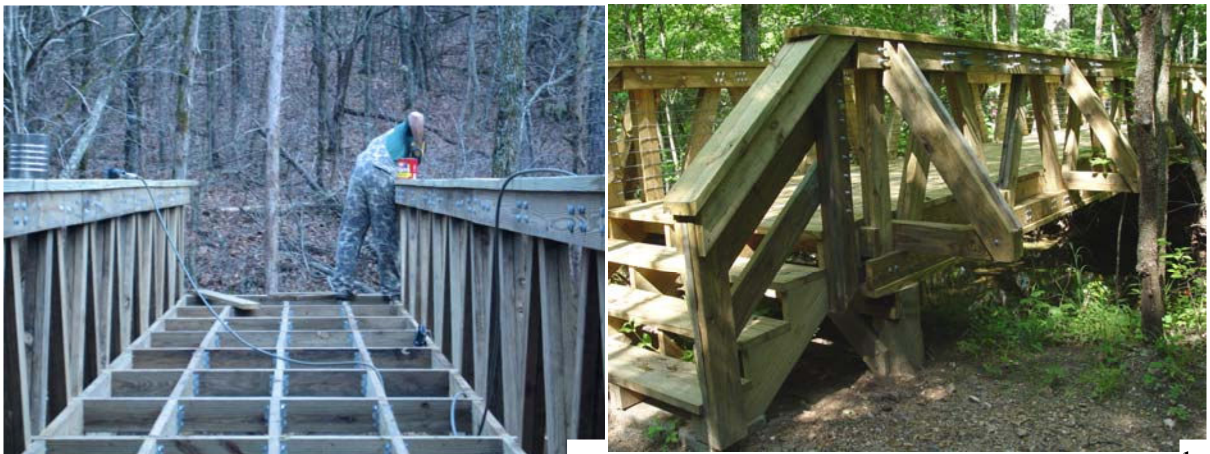
three weeks. During the approval period an attempt was made to accelerate the construction phase by purchasing all of the 2x6 material and having the ONSC staff pre-cut it on their table saw using the cutting schedule provided in the construction drawings. While this was a risky undertaking there was a general feeling by all parties that the History and Heritage commission would certainly approve of the final design.

The actual construction of the bridged started the week before Thanksgiving break when the foundations were placed. Eighty 80-lb. sacks of donated and purchased “Quickcrete” were carried to the site and mixed in a small portable mixer to create the bridge foundations. Initially all construction was to be undertaken with only hand tools to eliminate any noise that power tools would create in the woods. However, the silver lining in the delay of getting the design approved was that construction also delayed to a period when no nature walks were scheduled. With no nature walks scheduled, the requirement for silence was somewhat ameliorated and the ONSC staff allowed the use of a small 5 KW generator and a 20 gal air compressor to support powered hand tools and a small electric concrete mixer. Following the Thanksgiving break the superstructure was started in what turned out to be one of the coldest Decembers on record in Arkansas. The weather conditions illustrated in Fig. 4 were typical for the most of the construction period. In addition, the three week delay caused construction to run into the final exam period for the students. Postponing construction to the New Year was not an alternative since 13 of the 15 students were graduating and would be leaving the area right after final exams. A self imposed requirement among all the students was that everyone was required to work on the bridge for at least 15 hrs. Most worked two or three times that amount in brutal weather conditions to complete the superstructure. The student construction phase was completed on a Spring like 20^{o} F day in the middle of December. Figure 5a shows the state of the bridge at the conclusion of the student construction phase, while Figure 5b shows the completed bridge as it looked at the dedication some six months later.

Figure 4. Partially completed bridge superstructure showing ongoing construction in freezing weather conditions.

Assessment

Immediately following the student phase of construction the CE faculty and the ONSC staff and some members the board of direction of the ONSC met to informally assess the success of the project. All agreed that the students did a remarkable job of completing the design and the bulk of the construction in such a short period of time. The results were actually "beyond my wildest expectations", said one ONSC board member. There was some remorse that there was not more overlap and interaction between the students and the Pioneers during the constructions process. However, it was acknowledged that the delay in approval of the plans mandated the separation of efforts. Everyone at the ONSC was extremely impressed by the professionalism displayed by the students during their presentations. One member of the board said "they made me feel like I was a valued client who was paying dearly for their services and they explained everything in



a b

Figure 5 a). Completed superstructure. b.) Completed bridge.

terms I could understand". Another member was delighted by the fact that the design specifically addressed affordability and allowed them to purchase all of the lumber at a "great" price. Overall, the ONSC was very pleased by the outcome of the project.

Anecdotal evidence collected through informal discussions with the students at the conclusion of the semester suggests they were very happy with the design and construction phase of the Senior Design course; however, they were not very happy with the way the professional component of the course (ethics, business models, global awareness and leadership) was handled. They felt there was simply too much work involved for the credit hours allocated to the course. Twelve months after the completion of the course a survey was administered to assess the service component of the course and how the course had prepared them for the work place. Responses to survey questions were compiled on a Lickert scale with 1 indicating strong disagreement and 5 indicating strong agreement. The survey was sent to all 15 students with 11 responses to date. One hundred percent of the respondents either agreed or strongly agreed that their design project contributed significantly to their preparation for entering the workplace. One hundred percent also agreed or strongly agreed that their efforts were appreciated by the ONSC. Equally strong at the opposite end of the spectrum of responses was the notion that all volunteer groups were equally engaged and carried their weight in the project and that the project was of suitable magnitude for a one semester course. Responses to other questions were not nearly as polarized. The complete survey and an average value of the responses are given in Appendix 1.

Lessons Learned

Perhaps the most important lesson learned is that even a seemingly small project can become overwhelming if the time line is not adhered to by all parties. At the beginning of the course everyone agreed that the goal of completing construction of the bridge in one semester was completely doable. However, minor delays in creating designs and major delays in outside approval of designs caused a significant problem with the actual construction at the end of the semester.

Student selection of a highly motivated project manager is essential to keeping things on track. The manager for this project was well qualified and was able to keep all groups on track.

The students must develop and internally approve their own schedules. Student must give their project manager weekly briefings on progress and problem areas.

Too much direction from the faculty thwarts creativity and causes students to relinquish ownership of the project. Students will gladly shed any responsibility the faculty is willing to pick up. While faculty oversight is important to ensure the work is technically correct, students must take ownership of the entire project for this experience to be a real success. Faculty must listen, question and listen again, rather than direct.

Pick a project that is close to home. The ONSC is located about 45 miles from campus. This physical separation presented a significant logistical challenge, especially during the construction period.

Beware of "in-kind" donations. Most of the materials that were donated were, in the end, unusable or presented more trouble than they were worth. For example, the donated Quickcrete was in the form of broken bags that had not been properly stored. They were difficult to transport and the product was already hydrated. To top it all off the students had to go to multiple locations to pick up the donations, a job the Pioneers were supposed to complete.

Establish goals, deliverables and timelines for all volunteers groups and keep them talking to make sure everything stays on schedule. At times the other volunteer groups could not react or provide a service that was previously agreed to. This resulted in the students picking up the slack.

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Appendix A

Senior Design Assessment Survey

This questionnaire is one vehicle that is being used to capture the class' perceptions of your senior design course and service prject. There are a series of questions that require a response from 1 to 5 and there is a space at the end of the questionnaire to provide written comments, should you desire to do so.

Responses: 1 – Strongly Disagree, 2 – Disagree, 3 – Undecided, 4 – Agree, 5 – Strongly Agree.

Please circle or place an x below your response.

			Average of 11 responses
1.	Design/project portion of my senior design experience was better than I thought it would be based on my preconceived beliefs	1 2 3 4 5	(3.9)
2.	The professional component (ethics, current events, etc.) of my senior design experience was better than I thought it would be based on my preconceived beliefs.	1 2 3 4 5	(2.4)
3.	The grade I got in this course is what I expected	1 2 3 4 5	(3.5)
4.	The credit hours (4) assigned to this course were appropriate for the required work.	1 2 3 4 5	(2.0)
5.	The technical complexity of the design project was appropriate for a one semester senior level course.	1 2 3 4 5	(4.5)
6.	The scope of work for the design project was appropriate for a one semester course.	1 2 3 4 5	(2.3)
7.	I was technically prepared to undertake the design project before starting senior design.	1 2 3 4 5	(2.6)
8.	I learned a lot about the integrated design process that I did not know before taking senior design.	1 2 3 4 5	(4.2)
9.	The professional skills I learned and exercised in senior design better prepared me for the CE workplace. (communication, ethics, global affairs, etc.)	1 2 3 4 5	(3.4)
10.	The technical skills I learned in the design and construction of the project better prepared me for the CE workplace.	1 2 3 4 5	(4.6)
11.	The schedule initially created for the design project was realistic.	1 2 3 4 5	(3.8)
12.	All project milestones were successfully met in most cases.	1 2 3 4 5	(4.1)
13.	All student members on the project team contributed what was assigned to and expected of them.	1 2 3 4 5	(3.2)
14.	Student management of the project was adequate. It was well organized.	1 2 3 4 5	(4.6)
15.	Other volunteer organizations provided what was expected of them on the project.	1 2 3 4 5	(1.5)
16.	Faculty involvement and guidance in this project was about right.	1 2 3 4 5	(4.0)
17.	Staff involvement in the project from ONSC was about right.	1 2 3 4 5	(4.7)
18.	Volunteer organization involvement in this project was about right.	1 2 3 4 5	(1.5)
19.	I felt a great sense of accomplishment at the end of the project.	1 2 3 4 5	(3.8)
20.	I feel I provided a great service to the ONSC.	1 2 3 4 5	(4.8)
20.	My efforts were truly appreciated by the ONSC.	1 2 3 4 5	(4.2)
21.	I was properly recognized for my work in this project.	1 2 3 4 5	(2.3)
22.	I am more likely to become involved in community service activities in the future as a result of being involved in the project.	1 2 3 4 5	(3.6)
23.	Overall, the project made me a more product employee for my current	1 2 3 4 5	(4.2)

Please provide any written comments below or on the reverse side.