An Innovative Approach to a Cross-Disciplinary Senior Design Project

Saeed Moaveni, Ph.D., P.E.
College of Technology and Computer Science
East Carolina University
Greenville, NC 27858
moavenis@ecu.edu

Karen C. Chou, Ph.D., P.E.
Department of Mechanical and Civil Engineering
Minnesota State University
Mankato, MN 56001
karen.chou@mnsu.edu

Abstract

In this paper, we will discuss a collaborative effort between civil engineering and mechanical engineering faculty, students, and industry in a capstone senior design project. It is well known that funding for educational laboratory equipment is limited. It is also known that when industry upgrades their equipment they donate some of their replaced equipment to universities. This type of activity renders an attractive opportunity for upgrading educational laboratory equipment and at the same time providing realistic design projects for students and collaboration among various programs within a university. In this type of collaboration, the students in the design team work closely with faculty and students from another program to modify the donated equipment to meet their needs. The design objectives are defined by the faculty and students who will use the modified apparatus. This type of project not only meets the goals of a major design experience to emulate the practice of planning and designing of an engineering project, but also provides product development experience and technical communication activities such as writing a user's manual and experimental procedure. Another unique feature of this type of collaboration is that the design team has a direct interaction with the end-users (the students). This type of interaction may not exist in other projects including the ones sponsored by industry. In this paper, we will share in detail our experience in dealing with and managing this type of collaborative project.

Introduction

It is a well known fact that the university funding for educational laboratory equipment is usually scarce and does not typically meet the educational objectives of engineering and technology programs. It is also well known that hands-on laboratory experience enhances students learning and better prepares them for practice. This common lack of sufficient financial support for laboratory equipment in our civil engineering program compelled us to look for alternatives. As is the case in many other universities, the need for educational equipment is first conveyed to the department chair. In our mechanical and civil engineering department, after receiving the equipment request and considering the budget and the complexity of the equipment (experimental setup) requested, we typically consider two additional approaches, namely, design and fabricate the entire test apparatus in house, or seek slightly old equipment from industry through donation and modify it to meet the need. In this paper, we present an example of a project that deals with modifying donated equipment— a direct shear apparatus to measure shear strength of sand—to meet the educational objective of our civil engineering program. After receiving the donated equipment from the Minnesota Department of Transportation (MnDOT), the challenge became as how to modify the donated equipment to meet the need of our geotechnical engineering lab. To solve this problem, we turned to our mechanical engineering colleagues and seniors for a solution. We created a capstone design project that did not only provided a realistic design experience for the mechanical engineering students, but it also addressed the need of the geotechnical engineering lab in our civil engineering program.

The Capstone Design Project

The capstone design project in our mechanical engineering program, at Minnesota State University, is a two-semester course sequence. With the goal that mechanical engineering graduates should experience how a mechanical engineering project is planned and designed in industry, the two-course design sequence focuses on both the overall design process of a project and on design calculations and meets ABET criterion 4, which states that "*students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.*"

The design team is also required to consider numerous technical/non-technical factors associated with the project and to seek feedback on their preliminary design from their peers, faculty advisor, and the engineers from the company donating the equipment. During the first semester, students are assigned the project, faculty advisors, and the engineering advisors from the sponsoring company. During the second semester, students are expected to complete the project by a target date even if the project is behind schedule by the end of the first semester. Communication and interpersonal skills are stressed extensively during the design project. The team gives formal and informal presentations throughout the year. All of our mechanical engineering design projects include the following tasks:

- Define the project objectives
- Investigate alternate concepts to achieve objectives
- Conduct engineering analyses and create engineering drawings
- Develop proof of concept model
- Test and evaluate
- Submit fall semester and final reports
- Prepare a schedule for project completion using a Gantt chart
- Present preliminary design to students, faculty, engineers, and anyone interested in the project
- Meet with faculty advisor(s) weekly and document progress and activities
- Meet with engineers from the company donating the equipment
- Present the final project to students, faculty, engineers, and anyone interested in the project

Figure 1 shows the organization and execution of a typical mechanical engineering design project. The cross-disciplinary nature of the design project presented here was incorporated into Figure 1 to reflect the participation of the company donating the equipment, the faculty from the other program (civil engineering), and the end-users (civil engineering students). The organization and execution of the cross-discipline design project is shown in Fig. 2. In the figure, boxes with double-line borders represent the steps unique to the cross-discipline design project.

***The donated equipment*—**When Minnesota Department of Transportation (MnDOT) received their new fully automated-digital direct shear testing equipment, they donated their manual-analog apparatus to our civil engineering program. This donation rendered an attractive opportunity for enhancing our geotechnical engineering laboratory and adding a much needed undergraduate soil mechanics experiment to the civil engineering program. At the same time the donated equipment provided a realistic capstone design project for our mechanical engineering students. The design project also provided a means for collaboration between our mechanical and civil engineering programs within our department. In this collaboration, the mechanical engineering students in the design team worked closely with faculty and students from civil engineering program to modify the donated manual-analog direct shear testing apparatus to meet their soil mechanics experiment needs. Another unique feature of this collaboration was that the design team had direct interactions with the end-users (the civil engineering students), which typically does not exist in other types of capstone projects. The modified apparatus was evaluated by the end-users, the civil engineering students, by measuring the shear strength of sand, while following the operational procedure written by the mechanical engineering design team. This type of project not only meets the goals of a major design experience to emulate the practice of planning and designing of an engineering project, but also provides product development experience and technical communication activities such as writing a user's manual and experimental procedure.

The Design Process

In this section we will explain in detail the tasks associated with the design process.

***Meeting with faculty advisor(s)*—**as a first step, the design team is assigned a mechanical engineering faculty advisor. Students (the design team) meet with their faculty advisor to learn about the design project and its expectations. They schedule times for their weekly meetings and discuss other routine design activities such as maintaining a design logbook.

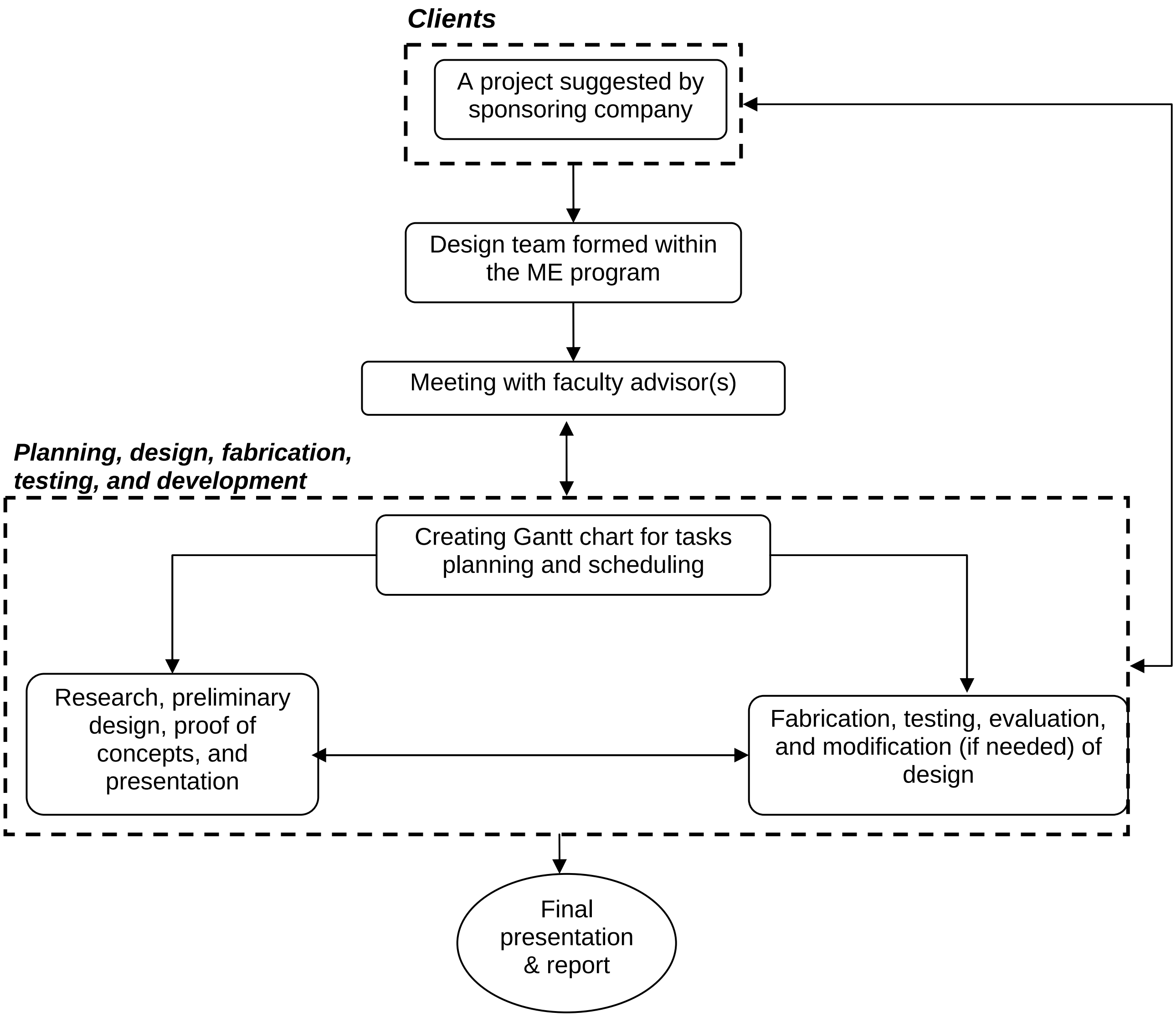

Figure 1. Organization and execution of a typical mechanical engineering design project at MSU.

Meeting with Engineers and Technicians from the donating company —in a typical mechanical engineering design project, after meeting with their faculty advisor, the design team would meet with representatives from the sponsoring company. In this project, instead, the design team met with representatives from the state organization, MnDOT's geotechnical engineering lab who had donated the equipment. The design team met with engineers and technician who have used the equipment. Students first attempted to gather as much information as possible about the apparatus. With the permission of MnDOT, they also took pictures of the lab space and the apparatus setup, and learned about the features of the new equipment that replaced the one that was being donated.

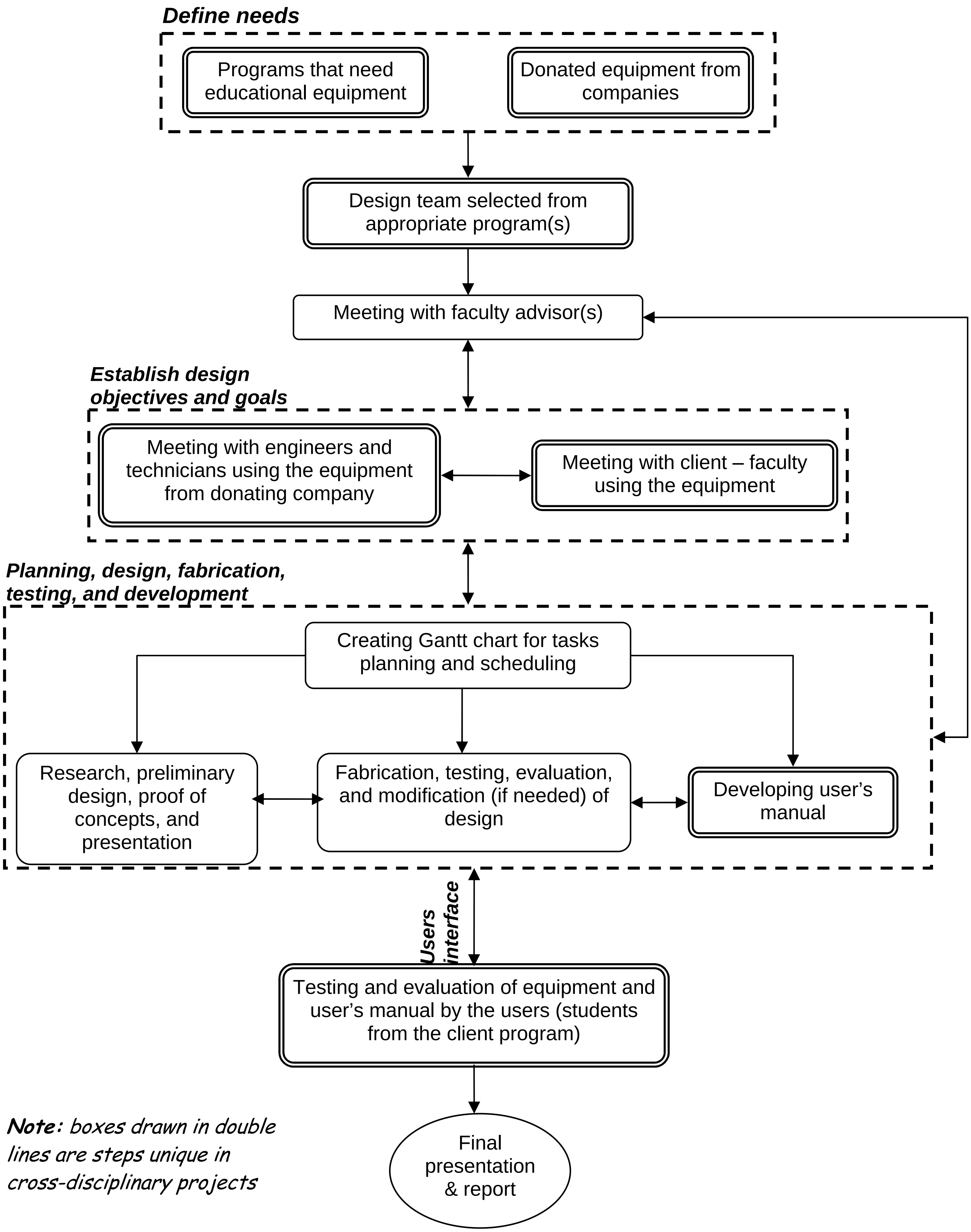

Figure 2. Organization and execution of a cross-disciplinary design project at MSU.

Meeting with the client—next, to establish the specific design objectives and goals for the project, the design team met with the client, the faculty who requested the equipment for testing shear strength of sand.

The primary objective of this cross-disciplinary design project was to fully automate the donated direct shear testing equipment (for sand) to meet the specifications described by the civil engineering faculty and his students who will use the equipment to conduct soil mechanics experiments.

Creating a Gantt chart (task chart)—to ensure that the project is completed on time and within the allocated budget, the design team had to first prepare a Gantt chart (task chart). The task chart assigns adequate amount of time for various project activities such as establishing specifications, presentations, background research on the apparatus, concept development, selection of a concept, analysis, producing detailed drawings, ordering parts, fabrication, instrumentation of the test apparatus, producing lab manual, testing, modifications, and end of year oral presentation and final written report.

The remaining steps in the design process are similar to those of a traditional design. Although the direct shear testing apparatus project may appear to be small in scope and simple at first glance, the project was as challenging as a typical capstone design project. The design included modifications to the apparatus to accept a linear variable differential transformer (LVDT), a new force transducer, and a control system to measure the relative lateral movement of the sand shear planes under a load. In addition, the design team developed a software using LabView to perform fully automated data acquisition. The original mechanically driven system with gears and belts was also modified to accommodate the automation.

Student Evaluation

The term grade for each student in the design team was determined based on performance in weekly meetings and progress reports, interim and final presentations, final written report, peer evaluation, and design documentation maintained in a notebook.

Weekly meeting and progress reports—the team was required to meet with the faculty advisor weekly and submit a progress report addressing three items: what was done during last week, what is to be done next week, and address unexpected major design issues that may have arisen during the previous week and how they will be handled.

Interim and final presentations—the team was required to give a number of presentations to the design class discussing progress made in their project. For the final presentation, the public, representatives from the company donating the equipment, and the client were invited to attend.

Final written report—the design team was required to provide a final written report with the following items: project overview, project scheduling and planning, design specifications and requested modifications, engineering drawings of all modifications, lab manual, and other pertinent materials.

Peer evaluation**—**Students were asked to evaluate the performance of other members of the design team. They were asked to use a numerical scale of 0 (no contribution) to 5(the most contribution) to evaluate their team members' performance in: (a) teamwork, (b) helpfulness, (c) contribution to the project, (d) research effort, (e) knowledge of the project, (f) participation, and (g) overall performance. In addition, each student was required to include a self assessment of his/her specific contribution to the project.

Design Documentation maintained in a notebook**—**Students had to maintain a design logbook with the records of all meetings, calculations, drawings, and so on.

Producing a user's manual—in addition to the final written, the team working on the direct shear project was required to produce a lab manual that would be used by the civil engineering students. The user's manual included, information about the apparatus, operating procedure, experimental objectives, theoretical background related to the experiments, experimental procedure, blank data sheets, results sought, and the required discussion.

Testing by client and providing feedback**—**Most design projects are tested and evaluated by a design team to prove the design concept, and the final design is rarely assessed by the actual end-users. In this project, however, the end-users, the civil engineering students tested the product. They followed the instructions and information given in the user's manual and conducted the direct shear test. Any ambiguity in experimental procedure, theoretical background, sample data sheet, or expected results were reported to the design team for clarification and revision.

Concluding Remarks

In this paper we discussed an innovative approach to a cross-disciplinary senior design project that meets the ABET criterion 4 (major design experience) and at the same time serves to create additional laboratory equipment for an undergraduate curriculum in another engineering program. The modified direct shear testing apparatus—discussed in this paper—has been used successfully for the past three years by the civil engineering (CE) students.

Upon the completion of the project, informal surveys—with a focus on the cross-disciplinary nature of the project—were conducted to evaluate the positive and negative aspects of this collaborative project. The design team (ME students), the end-users (CE students) and the faculty, all found the project to be beneficial and by and large had positive comments. The survey revealed the following positive aspects: (1) This cross-disciplinary project offered many benefits including small cost and strong interaction among students and faculty from different programs. (2) The traditional approach in providing realistic design experience for mechanical engineering students is to seek a project from a sponsoring company. While the end product may be used in other fields including civil engineering, the students (the design team) rarely have an opportunity to have direct interaction with the end-user. (3) Although the civil engineering students were not involved directly with the design of the product, they participated as end-users and contributed to the learning experience of their peers as well as themselves. Our civil engineering students learned first hand the contribution of other disciplines to their area. It was important to them to recognize how one engineering discipline contributes to another. (4) The project not only provided the mechanical engineering students with product development process experience, but it also provided them with technical communication activities such as preparing a user’s manual and writing experimental procedures.

The survey also showed that this type of project possesses some challenges. When faculty and students from multiple programs are involved in a project, careful planning and scheduling of the project is a must!

Since the success of the direct shear project, another team of mechanical engineering (ME) students designed and built a triaxial consolidation testing apparatus—for the geotechnical engineering lab—to test the strength of clay. Another cross-disciplinary project is currently being formulated to design, fabricate, and instrument structural models. These models will be used by ME and CE students in our structural analysis lab.

References

LabView Manual, National Instruments.

Biographical Information

SAEED MOAVENI is Associate Dean of College of Technology and Computer Science at East Carolina University and former Chair of Department of Mechanical and Civil Engineering at Minnesota State University, Mankato. Dr. Moaveni has over 20 years of professional experience and is a registered P.E. in New York.

KAREN C. CHOU is Professor and Civil Engineering Coordinator at Minnesota State University, Mankato. Dr. Chou has over 25 years of professional experience and is a registered P.E. in New York, Tennessee, and Minnesota.