AC 2007-2427: BALANCING LEARNING OBJECTIVES AND SUCCESS IN A MULTIDISCIPLINARY SENIOR DESIGN PROJECT

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Balancing Learning Objectives and Success in a Multidisciplinary Senior Design Project

Abstract—In the Fall of 2005, a team of five engineering seniors was assigned a multidisciplinary senior project in which they were to design and build a power generation system for a small village on Ometepe Island in Lake Nicaragua. The power generated was to be used for lights in a small clinic and a classroom, a refrigerator for vaccines, and an emergency radio. In light of tight budgetary constraints, students decided to augment their budget through fund-raising and expand the scope of the project to a fully-installed, on-site, working prototype, which would require all five students to travel to the village in Nicaragua. This aggressive plan of work was instituted by the students themselves.

As instructors for this course, we were charged with two important tasks: to guide the students towards the learning objectives set forth for the course and to help the students fulfill their goal of providing power to a village in need. In previous implementations of projects for this course, the small scale of former projects allowed the course to set the schedule for assignments, reports, and prototype progress. However, the real-world nature of the Nicaragua project sought to drive the schedule of the course, these two needs at times appearing to conflict with each other. This paper discusses these apparent conflicts, the decisions made by the adviser and other faculty members in the course to resolve these conflicts, and the reasoning that drove these decisions. The successes of the project will also be discussed. Two of these successes are that four of the five team members were able to travel to Nicaragua to install the wind generator and that it has been operating continually since March 2006.

Outline

1. Introduction

One of the many challenges that face instructors of a design course is ensuring that all learning objectives are being met for multiple design teams working on significantly different projects. Although this has often been a challenge in the senior design course sequence at ________ University, it became even more challenging when an international service project was selected for the Fall 2005 semester of the course. The goal of this project was to provide a power source to a remote village in Nicaragua so that the villagers could have lights in a school and health clinic as well as the ability to contact a local hospital in emergencies. Spring break was found to be the best time to implement this project, which provided more challenges due to the general course schedule conflicting with the planned schedule for this project. Further complicating things was the pressure to succeed on a project as important as this one. While in many cases the learning experience works best when students are allowed to fail and learn from these failures, the benefits that a successful project could bring to a community in need encouraged course instructors to more closely guide the team while still allowing them to explore solutions to the problems on their own.

This paper will describe the current course structure in the multidisciplinary senior design course at ________ University as well as the goal of this particular project. The conflicts between the this service-based project and the structure of the course as well as the resolution of these conflicts will follow. Finally, a discussion of the successes of the project and the lessons that were learned, as well as the future impacts of this experience will conclude this paper.

2. Multidisciplinary Senior Design Projects at ________ University

The senior project courses at ________ University have undergone a number of improvements over the past decade. Electrical, computer, and mechanical engineering students now take a year-long senior design course sequence in which they work in multidisciplinary teams composed of four to six students from at least two of the three disciplines. All teams have a primary advisor from one of the engineering disciplines and a secondary technical advisor from another engineering discipline.[1-2] Past projects include national design competitions[3], service-oriented project, and work with individuals or companies to develop prototypes of new products.

In GE 497, students are given some choice in which project they will be on. Every student must rank up to five projects from a list provided by the faculty. (Students can also suggest project ideas to be placed on this list; these ideas must first be approved by the faculty to ensure that they meet the objectives for this course.) Students also have some choice in who their team members will be. If there is a fellow student whom they would like to work with they can say so, and if there is a fellow student with whom they just don't get along, they can also make that known to the instructors. By the second week of the class, instructors make the team assignments so that each team can get started as soon as possible.

All members of the team are expected to contribute equally to the conceptual design, the construction and testing of the prototype, and the documentation of the final results of the project.[4] Extensive communication is required, including individual and team presentations, written proposals and final reports, and creation of a team video and a team poster.

The multidisciplinary nature of the teams involved in these projects has provided many benefits for our students, as reflected in the observations of teams at other universities with similar multidisciplinary teams.[5-8] In particular, the quality of physical prototypes has dramatically improved since the multidisciplinary structure was instituted, and the breadth and scope of projects that can be completed by our multidisciplinary teams far exceeds what could be addressed by teams representing a single discipline.

3. Ometepe Island and the Village of La Palma

Ometepe Island is a volcanic island made up of one active volcano and one inactive volcano. The two volcanoes naturally divide the island into two halves. The cities and towns on the northern half, surrounding the active volcano, benefit from a power grid with electricity supplied by four diesel generators. The poorer half of the island is without power, and due to inadequate maintenance of the roads, inclement weather conditions, and rough terrain, travel is difficult between the electrified parts of Ometepe Island and those without power. Approximately 35,000 people live on Ometepe Island and almost 4,500 of those live without electricity or telephone or radio communication to the rest of the island.

La Palma is one of the larger villages on the southern half of Ometepe and is one of the farthest from the power grid. It has a small clinic which has a waiting room, a small one-room pharmacy, two examination rooms, a doctor's office, and an operating room. A doctor visits this clinic once a week, but due to the lack of electricity, it is not worthwhile for him to visit more often. In emergency situations, residents of La Palma have no communication with the hospital and must travel two hours by truck over the rough terrain to reach medical attention.

The goal of this project was to deliver a sustainable power source to the health clinic and a school room in the village of La Palma. The student team determined that enough power should be generated for lights in the clinic and the school room, a small refrigerator for vaccines in the clinic, and a radio to communicate with the hospital in Altagracia.

4. Conflicts Between Course Structure/History and the La Palma Project

As mentioned earlier, instructors assign students to their projects based on feedback from the students. Teams typically consist of two to three mechanical engineering majors and two to three electrical or computer engineering majors. Each team is given a maximum budget limit to work with, which depends on the project and whether there is any external funding available. Typically this budget is in the range of $500-$1,000. Due to this financial constraint, a trip to Nicaragua could not be guaranteed for the team chosen for this project, and students selecting this in their top five were aware of this. In the first meeting of the La Palma team, students were asked if they wanted to set the goal of implementing this project in La Palma even if it meant that any funding beyond the initial budget of $500 would need to be raised by themselves and they unanimously agreed.

Typical projects in the senior design course require teams to select motors, valves, microcontrollers, etc. to incorporate into their design. Circuits, frames, and other components are usually designed and manufactured by the students. The wind generator designed by the La Palma team presented a dilemma for the team advisor. Much of the system was comprised of purchased components that were too complex to manufacture themselves. For example, an initial attempt at making the blades for the wind generator found that it was impossible, given the resources available, to make them at the level of detail necessary. Because of this, the final design contained much less manufacturing and fabrication than most projects in the course. Based on this observation, the next conflict arose: was this project challenging enough, technically, to ensure that the course learning objectives would be met?

The Spring semester for the senior design course requires that teams complete their physical prototype by late March and then test their prototype to be sure that it meets the system design requirements determined early in the Fall semester. Finally, teams then present their projects to the public at an open house in late April, just before the end of the semester. Travel plans for the Nicaragua team were finalized in early February for their trip to install the wind generator in La Palma over their spring break in the first week of March. Consequently, this team would not have a prototype on campus during the testing phase or for the open house. This team would essentially have to complete a two-semester course in a semester and a half.

5. Resolution of Conflicts

Any time one team of students has the opportunity to do something special, there should be at least a discussion about whether this is fair to every student in the course. For example, in this situation, it was important for the instructors of the course to have a valid response should other teams question why one group of students get to travel while the other nine teams would not have this opportunity. Fortunately, the structure of this course was very helpful in preventing this from becoming an issue. Every student in the course has some input as to what team they will be placed on. Because of this, each student was aware of the opportunity to travel or at the very least had the opportunity to select this project. Had the team assignments been made randomly or by some other means, students may have become envious.

As for the technical complexity of the project, when compared to other projects that were completed for this course, at first glance it seems to be on the low-technology end of the spectrum. This same year one team created a version of a Segway and another designed equipment for solar furnace research. However, when all aspects of the project were taken into consideration, the level of difficulty and technical complexity for this project was beyond that of other projects that were completed during this school year. For example, constraints for this project were significantly more challenging than those of others. The La Palma team needed to ensure that the components they purchased were going to be reliable, low cost, and easily replaceable from a remote location in a developing country. They also needed to be sure that the components could either be transported in their checked luggage, shipped to Nicaragua, or purchased in Managua. Finally, other difficulties that needed to be considered were constraints due to the location of the installed wind generator. The team needed to install the system in an environment that had no accessible electricity, limited metal working capabilities and hardware supplies, and little electrical diagnostic equipment. Any challenges encountered would be (and as was learned later, definitely were) difficult to overcome in this type of environment. In the end, the students involved in this project faced as many and as difficult technical challenges as their peers while working under the pressures of being in a completely new culture/environment.

The third challenge to the course instructors was resolving the schedule constraints required by this project when placed into the existing, well-defined structure of the course. As was mentioned, the logical travel time for installing the system was spring break. Typically the prototypes for this course are to be completed by the end of March, not the beginning. Once completed they must be tested to ensure that they meet the system design requirements, completing the design cycle for this course. During the late Fall and early Spring semesters, the La Palma team had two priorities to undertake for this project. First they needed to be able to design and create a wind generation system capable of charging two twelve-volt deep-cycle batteries. But they were also under pressure from themselves to locate funding to be able to travel to La Palma to install the system. Although they would not have the luxury of having a testable prototype on campus after the installation, they also did not have enough time to complete the prototype early enough to do rigorous testing before traveling to Ometepe. To resolve this issue, the team did as much testing as was possible in the limited time available, both before the trip and after the installation was completed and before returning home. Since they would be unable to do the rigorous testing back on campus in the final month and a half of the semester, a clever idea was suggested. Instead of writing a detailed test report, the team volunteered to write a manual and troubleshooting guide so that the villagers would have some means of maintaining the wind generator in the event that something failed.

6. Successes

Over $12,000 was raised for this project. Donations came from local university grants, from private donors – such as the Lilly Foundation as well as an anonymous alumnus, and from local businesses. Almost every purchased item for this project was discounted in some way. Without these donations, this project could not have been successful.

Of course the biggest success was that the system was completed in time and installed in March of 2006. Four of the five students on the project team were able to make the trip, as was the faculty advisor. Local villagers came out to welcome the team as well as to help with the installation. Prior to the trip the village members prepared a tower for the wind generator. After preparing the tree for mounting the generator, 20-30 village members raised the 30-ft tree using ropes and wooden supports fashioned on-the-fly from nearby tree limbs.

In only two days the generator was installed and the students were able to test their system in its final environment. As with any design, flaws were found, and the students had to determine how best to solve these problems using the limited resources available. By the fourth day, the electrical infrastructure was completed and lights were turned on in the school house and the clinic. Unfortunately the radio that was to be provided by the local hospital had not arrived but it has been confirmed since the trip that the radio has been installed and is working. Furthermore, it has also been confirmed that the generator is still turning and still providing a sustainable power source to this community.

Before leaving the village, esteemed members of the community and government representatives from the Ministries of Education and Health gave letters of commendation to the team, showing their gratitude and giving the students and their advisor hand-carved keys to the city of La Palma. This recognition symbolizes a connection between the people of La Palma and _________ University that continues to develop. The impact that this entire experience has had on the village of La Palma as well as the students in the project will affect their lives much longer than the intended learning objectives for the course that were also achieved.

7. Lessons Learned

Previous experiences with service learning projects in senior design were essential in paving the way for the success of this project. The earlier projects lead to results that were not helpful to the people being served or to the teams themselves. What the instructors of the course realized is that a project of this nature requires more relaxed guidelines as far as the complexity of the project is concerned. This does not mean that the course objectives are sacrificed, however. For example, many more complex prototypes that are developed tend to either just survive the testing phase or develop failures during the testing of the system requirements. Relaxing the complexity in allowing the design to largely become an integration of systems – combining elements that were purchased along with the design of some other components, the engineering design that was involved was not relaxed. What it did was to allow the team to spend less effort in manufacturing and spend more time in ensuring that their design would be able to withstand its intended environment. In other words, it allowed the team to create a product instead of a prototype.

This project also illustrated the necessity of making good decisions in assigning students to teams. As mentioned, students rank their top five projects with which they would most like to be involved. It is difficult to ensure that all students get their number one choice, but this project has shown how important that is. To be able to travel to Nicaragua, students involved in the La Palma project were required to complete a project sooner than other teams while still finding time to apply for various funding opportunities. Without the willingness to go the extra mile, this project would not have been successful, and it is impossible to expect anyone to work that hard if they do not care deeply about their project.

When taking on an international service project of this nature, it is important to be prepared for setbacks and be willing to take necessary risks. Working in environment that is outside of one's experiences is challenging. Problems that arise often cannot be solved by the usual means. However, planning in additional time and bringing additional resources was also helpful for this project.

In addition, many decisions for this project were based on insufficient information. Communication is extremely difficult when the project site is in a remote location and the two parties involved speak different languages. In these circumstances, calculated risks must be taken. For example, airfare was booked before any knowledge about the parameters of the tower were learned. Because of this, multiple designs were prepared for mounting the generator to the tower. Materials for each design were brought on the trip and in the end, an entirely new design was used once the exact tower was seen by the engineering team.

8. Conclusions and Future Projects

Throughout this experience, the success of the project was dependent on a schedule that often conflicted with the course's schedule. By adapting the course schedule judiciously, the course learning objectives were never compromised for this team of students. Also, by relaxing the complexity of the design, instructors allowed the team to make more efficient use of their time and focus more on the engineering design work. These decisions helped to give the students the freedom necessary for creating a successful project.

The contacts that were established in this remote, developing community has provided the opportunity for future projects. Currently a second senior design team is working to provide a sustainable power supply to an orphanage, also located on Ometepe Island. As this project develops, many of the lessons that were learned with the La Palma team are now being implemented. As before, this will provide a group of seniors a great opportunity to create a successful project while obtaining a learning experience that is enhanced with the cultural diversity and service of helping a community in need.

9. References

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