One Approach to Multidisciplinary Senior Design Projects

Bryan S. Goda, Andre H. Sayles, and Daniel C. Gray
Department of Electrical Engineering and Computer Science
US Military Academy
West Point, New York 10996

Abstract

At the U.S. Military Academy, the Department of Electrical Engineering and Computer Science was formed in 1989. Since that time, efforts have been underway to tap the synergism that can be derived from having the complementary disciplines under one directorship. HO scale model trains have become a focal point for a series of three senior design projects over a three year period. The first project was completed by a computer engineering major who was tasked to design and build a model train turntable. The turntable was PC controlled, used optical interrupts for sensing, and required C language text programming. The second project was completed by a team of three electrical engineering majors, two computer science majors, and one engineering management major. Their task was to design and build a rotating crane system that would automatically place the correct load on a designated train car according to selections made via a PC windows interface. The third project incorporated lessons learned from the first two. Five electrical engineering majors, two computer science majors, and two mechanical engineering majors were required to design and build a more complex gantry crane system that performed the same functions as the rotating crane. This series of projects serves as a basis for examining a variety of issues associated with multidisciplinary design projects. Considerations include team leadership, evaluation and grading of students from other academic departments, resolution of scheduling conflicts, peer ratings within an interdisciplinary group, methods for trading students between disciplines, and enhanced learning opportunities. Lessons learned from these projects will prove invaluable to graduating engineers and the participating academic departments.

Project Concept Development

Group design projects involving electrical engineering and computer science majors have worked well for the previous two years. Both majors fall under the control of a single department, which allows partial control over course scheduling and availability of students. Projects have steadily grown in level of sophistication and difficulty. This year, we determined that a gantry crane project would exceed the capabilities of electrical engineering and computer science students due to mechanical engineering design requirements. Thus, the multidisciplinary approach was appropriate for the completion of this project.

Group design projects raise a multitude of questions. Some of the considerations are group composition, group leadership, faculty advisor interaction with team members, monitoring progress, managing and evaluation of students from other disciplines, and satisfying different design methodologies. In this paper, we attempt to answer some of these questions based on our approach to interdisciplinary design.

Group Selection and Composition

The electrical engineering senior design projects begin towards the end of the fall semester and continue throughout the spring semester. The creation of groups starts with a sign-up process for the electrical engineering majors in the fall. The target group size at this point in the process is four students, although the numbers have ranged from two to five. Electrical engineering majors are provided with an information packet that contains a review of the engineering design process, a discussion of project requirements, a description of the available projects, and a sign-up sheet. Students are expected to prioritize their top three project selections, nominate up to two other students whom they may want to work with for each selection, and state whether or not they would like to be the team leader for each selection. This year, students also had an opportunity to name students they would hope to not have to work with. Students often volunteer to be the leader for one of their three choices, but not for all. The two nominations for team members are also dependent upon the project selected.

Selection of a qualified group leader is a key part of forming a project team. Peer leadership in an academic environment is particularly challenging due

to different standards of performance among team members and competing demands placed on students by other courses and activities. The first step in the process of placing students on teams is the selection of team leaders for the projects to be completed. Where possible, students who volunteer to be the leader are given their choice of project. Once the leader of each project team is established, faculty members have a chance to comment on the choices.

The remaining electrical engineering team members are selected through an iterative process that considers student preferences, team composition in terms of the Myers-Briggs Type Indicator, faculty recommendations, student performance in previous courses, and student qualifications and expertise in digital or analog electronics. Before the end of the fall semester, the new design team is required to research the problem that needs to be solved, write a technical project description, and a prepare a proposal for solving the problem. As part of this process, the team leader must look at the assigned resources and assess their collective ability to solve the problem. Typically, the assessment will lead to a request for additional team members, particularly computer science majors. Requests for students from other disciplines are handled by the project course director, who visits other academic departments to obtain the needed students by the beginning of the spring semester. By the end of January, the interdisciplinary teams are complete and administrative details have been worked out. The makeup of the 11 teams for the 1996 spring semester is shown in Table 1. Students from other disciplines were

Table 1. Students Assigned to Design Teams in 1996.

TEAM	EE	CS	ME	PHYS	OTHER
#1	4	2	2		1
#2	4	2			
#3	5	1			
#4	2				
#5	4			1	
#6	3	3			
#7	4	2			
#8	4	2			1
#9	5	2			
#10	2				1
#11	1	2			

a mathematics major, an engineering management major, and a Russian language major. These three students selected electrical engineering to fulfill the requirement for all Academy students to take at least five engineering courses. The five electrical engineering courses made available to non-majors includes the senior design project course.

Marklin Gantry Crane

The assessment of interdisciplinary design team performance discussed in this paper is based on Team #1 shown in Table 1, although the administrative details apply to all projects. The team was required to build a gantry crane system for HO scale model trains as shown in Figure 1. TheMarklin digital train is a

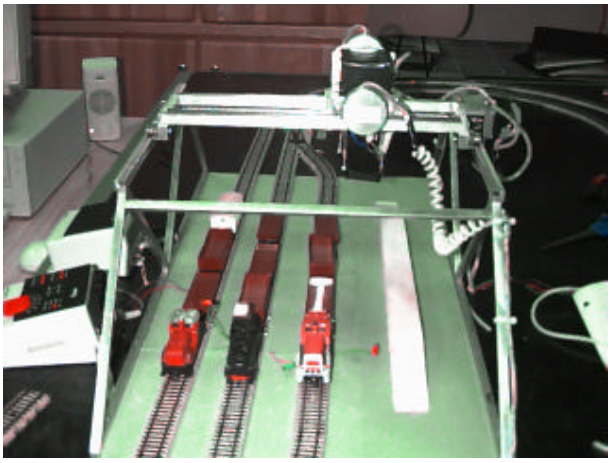

Figure 1. Completed Gantry Crane System Design.

three rail system that is fully computer controlled. The microprocessor in each engine can communicate via the third rail with any personal computer that has the required interface. From the computer screen, trains can be selected and remotely directed to perform operations such as coupling and de-coupling cars and running on a particular track. The project required the crane system to be able to automatically place any one of three designated loads on any car of any train in response to a click and drag operation on the computer screen.

The project team leader was responsible for determining the required tasks for the project and assigning them to team members. Leaving himself free to coordinate the work and assist where necessary, he assigned two students from the computer engineering stem and the language major to the hardware interface and digital logic tasks. He assigned the analog electronics student the task of designing and building the electromagnet for picking up the load. This same member was also responsible for selecting the required motors and designing the interface to the crane

structure. The two computer science majors had responsibility for the windows interface and all other software requirements. Finally, the two mechanical engineering students were tasked to design the crane, select materials, complete the CAD drawings, and assist the machinist with fabrication. Like the student team, the faculty advisor team was also interdisciplinary. The advisors included expertise in computer engineering, electric power, mechanical engineering, computer science, and electronics.

Monitoring and Evaluating Performance

All students who worked on the gantry crane were evaluated under the existing electrical engineering system, which is based on a total of 4000 possible points. Forty percent of the point total is based on assessment of individual performance as shown in Table 2. Grades were awarded to students based on a combination of individual work and team performance.

Table 2. Project Graded Requirements and Points

Graded Requirement	Individual	Team
Written Proposal		200
Oral Proposal Presentation		200
Individual Technical Report 1	100	
Peer Rating 1	100	
In-Progress Review 1		300
Individual Technical Report 2	100	
Peer Rating 2	100	
Critical Design Review		400
Individual Technical Report 3	100	
Peer Rating 3	100	
In-Progress Review 2		300
Individual Technical Report 4	100	
Peer Rating 4	100	
Project Demonstration		200
Individual Technical Report 5	100	
Peer Rating 5	100	
Final Oral Presentation		200
Final Written Report		400
Course Director Evaluation	200	
Advisor Group Dynamics Eval	200	100
Advisor/Mentor Professional	200	100
TOTAL	**1600**	**2400**

Peer ratings and an individual technical report were required approximately every seven attendances or three weeks. The technical report included a description of individual accomplishments in several areas related to the design process and a requirement to report the total time spent on the project during the rating period. Prior to obtaining grades for team-level events from the respective advisors, the course director provided an order of merit list for each requirement based on his evaluation of every team. The advisors then provided a letter grade for their teams without necessarily being restricted to the order of merit list. The two mechanical engineering majors received credit for the senior design course in their department, but worked full time for the electrical engineering team leader. The mechanical engineering advisor attended most of the progress reviews and accepted the grade provided. The two computer science students were evaluated under the electrical engineering system, but were also required to complete requirements placed on them by their computer science course director. Their grade was primarily based on the project work, but the computer science course director reserved the right to change the grade based on other considerations. All other students on the gantry crane team were graded in an electrical engineering course.

Project Coordination

Although the gantry crane project was very successful and a model project for the Academy, the coordination with other disciplines was challenging. The mechanical engineering project course met in the afternoon, while the electrical engineering courses met before lunch. Unfortunately, the mechanical engineering students had to attend other courses before lunch and never had a chance to work on the project during the designated time. One of the computer science majors was available during half of the two hour project block, but the other was not available due to other courses. The scheduling problem placed more responsibility on the student team leader than may be desirable. He had to find a time in the busy evening schedule to meet with his full group, while providing the leadership necessary to get everyone to attend. Typically, an opportunity was not available during these meetings to physically work on the project because it took more than an hour to just go over what each team member was doing and determine the next step for each task. Project subsystems had to be designed and built almost in isolation from other team members. The performance of the team leader in this case was remarkable, but it was not the same for every project. In a different project, the team leader did not adequately employ the computer science majors and placed them at risk of receiving a low grade on technical reports.

Lessons Learned

Our nine cadets all agreed that communications between the various disciplines is the key to success in an interdisciplinary project. Team members learned to rely on each other for expertise in their own fields and tried to assimilate how their efforts would be coordinated with the work of other team members. We were fortunate that our group leader maintained an outstanding flow of communications between the mechanical, electrical, and computer design sections. When one section ran into a problem, the other sections were notified and tried to continue on by simulating inputs so steady progress could be maintained.

Linking the individual sub-systems into a working design was the most time consuming part of the design process. The group initially projected a completion date of six weeks before finals, but the group completed the final project only two weeks before finals. When the crane structure came out of the machine shop, it was found that the stepper motors were not strong enough to drive the crane superstructure. Close coordination between the electrical and mechanical design sections as well as "cross training" between disciplines were key in solving such unexpected problems. The mechanical engineers remarked that this was the first time they had to build something that limited their design options based on another discipline.

Our cadets found that the design methodology we have constantly stressed actually works. Though we made them follow a fixed format, the students saw the value of going through the design process, especially in a simulated "real world" type design problem. Things do not always go as planned the first time, while other influences outside your discipline may drive your design. Good documentation circulated between the sections to update each team member on the other sections' progress. The end result was an outstanding, high quality , and interesting design.

The gantry crane project was presented to the Dean this year. Although it was very successful, a workshop involving the engineering departments and the registrar will be necessary to seek out ways to relieve the pressure on students caused by scheduling problems.

Conclusions

Interdisciplinary projects are a challenging and worthwhile addition to the design process. They should be continued in the future since they produce a better end product, give the student an outstanding perspective of other "real world" type design considerations, and offer a good group interaction exercise. This project was one of eight entered in the senior design competition. Three independent judges awarded first prize to this design group.

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Bryan S. Goda

Bryan Goda is an active duty Army Major specializing in mobile subscriber communications. He is a 1982 graduate of the United States Military Academy (BS) and a 1993 graduate of the University of Colorado (MSEE). He is currently assigned to 121st Signal, Kitzingen Germany. He has previously served in Germany and Operation Desert Storm. His research interests include parallel processing and real-time hardware software design. He was the primary advisor for the gantry crane project.

Daniel C. Gray

Daniel Gray is an active duty Army Captain. He received a BSEE degree from the United States Military Academy at West Point in 1985 and a master of science degree in Electrical Engineering from Duke University in 1994. He is currently assigned to the Department of Electrical Engineering and Computer Science at the United States Military Academy. His research interests include parallel processing and digital design. He is a member of the IEEE.

Andre H. Sayles

Andre Sayles is a Colonel in the Army and Director of the Electrical Engineering Program at the United States Military Academy. He received the BSEE degree from USMA in 1973, a master of science in electrical engineering from Georgia Tech in 1983, and the Ph.D. in electrical engineering from Georgia Tech in 1990. Research interests include electronics, optics, and optoelectronics. He is the course director for the senior design project course.