
AC 2011-1011: MULTIDISCIPLINARY ENGINEERING STUDENT PROJECTS

Matthew A. Dettman, P.E., Western Kentucky University

Mr. Dettman is the James D. Scott Professor of Civil Engineering at Western Kentucky University and his primary areas of interest are in Geotechnical Engineering and Construction Quality Control. He has been named the Civil Engineering Educator of the Year in the state of Kentucky, won the Ogden College award for Public Service, and currently serves on the Kentucky Governors Council for Earthquake Risk Reduction.

Walter L Collett, Western Kentucky University

Walter L. Collett received the B.S. and M.S. degrees in Electrical Engineering from Tennessee Technological University in 1990 and 1992, and the Ph.D. degree in Engineering from TTU in 1999. From 1999 until 2004 he was employed by Square D Company / Schneider Electric in Nashville, Tennessee, where he served as a senior electrical engineer, then as an engineering manager. He is currently an Associate Professor of Electrical Engineering at Western Kentucky University in Bowling Green. His research interests involve computational electromagnetics, application of electromagnetics to the analysis and design of electromechanical devices, and photonics.

Multidisciplinary Engineering Student Projects

Abstract

The role of the engineer in today's world is changing and expanding. Buildings and roads are becoming "smart", construction equipment communicates with satellites thousands of miles away while moving soil, surveyors now use lasers instead of tape measures, and the list goes on. The line between engineering disciplines still exists, but is growing faint and less defined. The Civil, Mechanical, and Electrical Engineering programs are attempting to find ways to bring the disciplines together on student projects. Part of the challenge of cross disciplinary projects is overcoming the fear of the lack of understanding of what other engineers actually do. By bringing students from multiple disciplines together on a single project, these barriers can be minimized, allowing students who were formerly segregated by classes to work together as a cohesive unit to solve a problem.

During the 2009-2010 academic year, students from the Electrical Engineering program worked with a Civil Engineering Capstone Design team on the latter's senior project. During the year long project, team meetings were held, requiring the students from each discipline to work together, share information, understand what the others were doing, and ultimately complete the project successfully. Upon completion, students were asked to reflect on their experience and what they gained from it. This paper presents the project the students were engaged in, the assessment of the outcomes, and some of the constraints that had to be overcome to make this project a reality. While the data set is small and results only preliminary, the outcome assessment is promising.

Introduction

These engineering programs began in 2000 with the first EAC/ABET accredited graduating classes in Civil, Mechanical, and Electrical Engineering matriculating in 2004. The mission of all three undergraduate-only programs is to deliver a project-based curriculum with a focus on preparing graduates for careers as engineering practitioners. Hands-on project experiences are integrated throughout each curriculum in order to build problem solving and team skills that will be valuable to the graduates' early career growth. In addition, all three programs are offered jointly with another institution. The nature of the joint relationship primarily impacts the students in that they must take 16 to 18 credit hours of coursework through Interactive Television (ITV) from the partnering institution.

Typically, project experiences are integrated into specific courses and few of them have involved working with students in other engineering disciplines. As these programs grow and mature, faculty are exploring opportunities for collaborative projects that cross disciplinary borders in order to aid the students maturity and growth in a profession where these borders are growing less defined¹. This paper presents preliminary findings on the value of cross disciplinary projects, employing a case study where a group of Civil Engineering students partnered with Electrical Engineering students (affectionately termed "ElectroCivil Engineering") in the completion of a capstone design project.

A significant amount of research into multi-disciplinary projects currently exists in engineering education. The purpose of this paper is to present a case history of a hands on, project based, multi-disciplinary project in a small undergraduate engineering department. Our experience is showing us that while there are certainly various constraints to be overcome, the effort to incorporate and manage these types of projects adds great value to the undergraduate educational experience.

The Project

Each year, a group of Civil Engineering students use the National Concrete Canoe Competition as their capstone design project. In recent years, concrete inlays have been incorporated into the design and construction of the canoe to demonstrate the aesthetic capabilities of concrete as well as innovative construction techniques. The process of installing the inlays has been to pour the concrete canoe, carve out patterns and letters by hand into the concrete, then backfill the carved out portion with a different colored concrete. The process was very tedious and time consuming and the ability to create fine detail was limited.

During the 2009-2010 academic year, an idea was presented by the students to create a device that would do the carving, or engraving, using a robotic device so that more intricate patterns could be created. The Electrical Engineering students were approached with the idea on whether or not this could be accomplished and two EE students volunteered for the project. The students then contacted an EE faculty member to serve as an advisor for the creation of the etching device who agreed to assist and a cross disciplinary team was formed.

Ultimately the EE students designed and built a 4 axis Computer Numerical Controlled (CNC) engraving device to create the inlays for the canoe team, as shown in Figure 1.



Figure 1 CNC Engraver

Throughout the design and construction of the CNC Engraver, the EE and CE students met regularly to troubleshoot the device. There were critical elements of the engraving process that the CE students required, such as dimensional restrictions of the lettering, reinforcement in the concrete that could not be cut by the engraver, and adequate depth of carving that would allow the void to be backfilled with a different colored concrete. These meetings were critical to the

success of the project. As the EE's developed prototypes, they would meet with the CE's to determine what worked and what didn't, which led to design modifications of both the engraver as well as the canoe. It was during these troubleshooting sessions and the back-and-forth design modifications where the students gained valuable experience in working with others outside of their discipline.

During the process of creating the CNC Engraver, the EE students became interested in another aspect of the concrete canoe design, which was the use of Shape Memory Alloy (SMA) wire as a concrete reinforcement. SMA wire is a material that can be pre-strained, or stretched, with the strain subsequently recovered and the wire returned to its original shape when exposed to heat². In concrete applications, the SMA wire is stretched and cast into the concrete. Once the concrete is cured, an electrical current is passed through the SMA wire to heat it and shrink it back to its original size. Since the SMA wire is embedded in the concrete, the wire is restrained from shrinking and the process effectively compresses the concrete making it stronger, or more resistant to tensile loads.

The EE students suggested the use of Labvolt and a F.L.I.R. thermal imaging camera to optimizing the current used to recover the pre-strain on the SMA wire. Labvolt is a workstation that contains a power supply along with various resistors that are used to control current. The Labvolt system was attached to the SMA wire and the current was varied until the optimal value was found that uniformly heated the wire. The F.L.I.R. thermal imaging camera was used to observe the wire to make sure that the heat was uniformly distributed. This process turned out to be extremely valuable as the thermal images revealed various heat sinks with the concrete that were not anticipated. The heat sinks were the result of the fact that carbon fiber mesh was also used as concrete reinforcement and in certain spots, the SMA wire came into contact with the carbon fiber mesh resulting in a heat sink. The current was adjusted accordingly to account for these sinks and to heat the wire along its full length. Had this process not been used, the SMA wire would not have been heated uniformly resulting in potentially damaged stresses being induced on the canoe. This secondary project proved valuable in achieving some of the desired outcomes of the project.

Student Outcomes

As a preliminary study, the faculty were interested in student perceptions of working with students outside of their own discipline. Using the basic principles of cooperative learning³, the students were told to develop the team goal, hold regular progress meetings, maximize the team's individual skills which have been broadened by including both EE and CE students, and help each other as well as hold each other accountable. Part of the accountability process was the use of team assessment forms⁴ at the conclusion of the project to rate each individual students performance. With these basic principles in place, the students were essentially on their own to complete the project with technical guidance from faculty as needed.

The student outcomes the faculty were interested in assessing on this project were very basic in nature and were established to determine if, overall, the students found the cross disciplinary experience valuable. The measured student outcomes were as follows:

1. Overall, was the experience valuable?

2. Did the experience [increase / decrease / not change] your willingness to work with others outside your own discipline?
3. Did you find students from another discipline more similar or more different than you initially thought?
4. Would you recommend this experience to other students?

These questions were asked of the 10 students in the capstone design course. In addition, they were asked to provide additional comments if they desired. For questions 1, 3, and 4, all of the students responded the same in that they found the experience valuable, they found students from another discipline more similar, and would recommend this experience to other students. For question 2, 80% responded with “increase” and 20% responded “not change”.

Some of the comments from students were of particular interest. Four of the students commented on the fact that it appears all engineering students essentially do the same thing, they just use different “stuff”. Three of the students commented that during troubleshooting sessions, basic topics such as stress and strain, force, math, and statics were a common language among all engineers. All of the students commented on what they saw as surprising similarities between the disciplines.

In addition to the student outcomes, faculty were interested in observing the students during progress and troubleshooting sessions. As part of the Project Based Learning approach in these engineering programs, active learning is a common theme in the student projects. Alison King⁵ describes what she calls guided reciprocal peer questioning as part of the active learning process. The types of questions she describes that induce higher-order thinking include

- How does...affect...?
- Why is....important?
- Explain why...
- What are the strengths and weaknesses of...?

The faculty were interested in seeing if the students had grasped these concepts in their freshman through juniors years and were able to apply them instinctively in this project. Faculty observations indicated that not only did students use this process, this active learning peer questioning essentially guided each troubleshooting session. For example, during the discussion of how fast the CNC engraver could engrave the concrete, the question of how does the speed of the engraving affect the engraving bit. As a result, the speed of the engraving was optimized to engrave the concrete as fast as possible without applying stresses to the bit that would cause it to break.

Constraints to Implementing Cross Disciplinary Projects

While the initial results of utilizing cross disciplinary projects in the engineering programs are very promising, there are existing constraints that must be taken into account before widespread or even permanent use of them are considered. In this case, the 3 primary constraints are ABET criteria⁶, University general education requirements, and the ITV requirements from our partnering institutions.

To maintain accreditation, all 3 programs must adhere to the ABET general criteria as well as the individual program criteria. At a minimum, ABET requires 32 credit hours of basic math and science. In addition, each program must fulfill program criteria which would include laboratory experiences, design sequences, and other requirements specific to each program which could amount to approximately 30 credit hours to fully satisfy individual program criteria. At this institution, 32 credit hours of general education are required, not including the math and science requirements which are already covered by ABET. This is above the national average for engineering programs which is 26.7 hours⁷. The joint nature of the engineering programs requires each student to take 16 to 18 credit hours via ITV from the partner institution. These 3 constraining factors account for approximately 110 to 112 credit hours of the engineering programs. With each of the programs requiring just over 130 credit hours, this provides approximately 8 courses in which technical electives, advanced topics, and capstone courses can be delivered. So while it has been shown that cross disciplinary projects can be very effective, proper planning must be used to find the best places for these types of opportunities to be introduced into the curriculum to enhance the educational experience of the student without jeopardizing any of the existing university constraints.

Efforts are being made to find commonalities in certain courses across all 3 programs to expand opportunities for cross disciplinary activities. For example, all 3 programs have a 2 credit hour course titled Freshman Experience. In this course, they are introduced to the engineering profession, taught study skills, computer skills, and engage in various project based activities to spark their creative engineering minds. Up until the Fall 2010 semester, each of the 3 programs had their own Freshman Experience course so all of the students in the course were in the same engineering discipline. In the Fall 2010 semester, a new course was implemented where all freshman engineering majors are in the same freshman experience course instead of breaking the students up by major. The goal is to foster more opportunities and interest in cross disciplinary projects by allowing the incoming freshman to see many of the similarities among the different engineering disciplines.

Conclusion

While the student data set is small and no definitive conclusions can be drawn at this point, the preliminary results from this cross disciplinary project are very promising. It was decided to continue this project into the current academic year with a new group of CE and EE students. Their charge is to improve on the CNC engraver, expand its capabilities, and to improve efficiency. Improvements they will be focusing on are to expand the range in which the engraver can work and the speed it can cut. The initial model had only a very small window it could work in (approximately 5 inches vertically by 36 inches horizontally) and it took about an hour or more to cut each letter. As a result of last year's efforts, the new students were excited and eager to get started. The EE program has incorporated their part of the project into a junior level design course. Although no formal data has been collected as of the writing of this paper, it should be noted that while last year's group of students entered the project with some skepticism about the "other students", this year's group exhibited none of the skepticism and were eager to get started. More data will be collected at the end of this academic year and will be presented at the conference. While some constraints do exist that must be considered, the benefits appear to be worth the effort in creating as many reasonable opportunities for cross disciplinary projects as possible.

Bibliography

1. Fruchter, R. and Lewis, S. (2003). "Mentoring Models in Support of P5BL in Architecture/Engineering/Construction Global Teamwork", *The International Journal of Engineering Education*, 19(5), 663-671.
2. Orvis, S.M. (2009). *Prestressing Concrete with Shape Memory Alloy Fibers*. Unpublished Masters thesis. California Polytechnic State University San Luis Obispo.
3. Felder, R.M. and Brent, R. (1994). Cooperative Learning in Technical Courses: Procedures, Pitfalls, and Payoffs, ERIC Document Reproduction Service Report ED 377038.
4. Kaufman, D.B., Felder, R.M., Fuller, H. (1999). Peer Ratings in Cooperative Learning Teams, *Proceedings of the 1999 Annual ASEE Meeting*, ASEE, June 1999.
5. King, A. (1993). "From Sage on the stage to guide on the side." *College Teaching* 41(1), 30-35.
6. Accreditation Board for Engineering and Technology (ABET). (2009). *Criteria for accrediting engineering programs, effective for evaluations during the 2010-2011 accreditation cycle*. www.abet.org
7. Russell, J.S. and Stouffer, W.B. (2005). "Survey of the National Civil Engineering Curriculum", *Journal of Professional Issues in Engineering Education and Practice*, ASCE, April 2005.