2007: UNDERGRADUATE RESEARCH OPPORTUNITIES IN SENIOR DESIGN

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Undergraduate Research Opportunities In Senior Design

Abstract

Senior design projects are typically consultant-based programs in which students interact with members of industry to complete a design project. Students benefit from a hands-on learning experience with a technical project, including analytical work, project management, and technical communication. However, another possibility is to have experimental, research-based projects sponsored by industry that expose students to academic research. These projects include analytical work, project management and technical communication, but also incorporate problem-based learning in which the students design and conduct experiments and analyze research data. At Seattle University, we have found that experimental, research-based design projects can be successfully incorporated into the civil and environmental engineering senior design capstone experience and that the students, faculty, and industry sponsors benefit from this approach. In this paper, we will present three experimental, research-based senior design projects that were coordinated and advised at Seattle University. Details will be provided about how the projects were attained, the scope of the work, the final outcomes, and the overall response of students, faculty, and industry sponsors.

Introduction

The benefits of exposing undergraduate students to research are well-known and documented. Recently, national attention has been paid to the importance of including experimental, research-based learning in undergraduate curricula[1-4]. Research has shown that students are more receptive to learning when they are engaged in problem-based learning[5]. One effective way to expose students to problem-based learning is through structured undergraduate research programs. In this context, students learn to synthesize research problems, design experimental programs, conduct research, and analyze results. In addition, these students develop more advanced communication skills, including report writing, public speaking, research documentation and dissemination, and interact with faculty in a much more interactive way than they would in a standard undergraduate curriculum. Students involved in undergraduate research are also exposed to the possibilities of graduate studies. Research has indicated that students who participate in undergraduate research considered the experience to be “very” or “extremely” important and were more likely to attend graduate school[6].

For faculty, conducting research at undergraduate institutions can be challenging due to lack of student interest and limited resources. Depending on the availability of student internships in the local consulting industry, students are often not keen on pursuing research opportunities, particularly if they are planning

to go into the consulting industry immediately after graduation. For these students, internships are more appealing because they are learning about their intended field and the internships will most likely lead to full-time job offers upon graduation. In addition, depending on the job market, students can often earn significantly more (around three times) at their internships than as research assistants.

Compared with research institutions, undergraduate universities tend to have a more limited research infrastructure. These limitations include fewer research equipments, less laboratory space, less computing facilities for modeling, and fewer technicians. In addition, the absence of graduate students makes the supervision and mentoring of undergraduates more challenging. At research institutions, undergraduate research assistants are usually paired with graduate students who guide them through the research process. However, at undergraduate institutions, faculty must completely assume this role. Overall, the infrastructural limitations at undergraduate institutions also affect the success of faculty applications for external grants. Thus, it can be difficult for faculty to find the resources necessary to conduct worthwhile research.

At Seattle University (SU), we have found that undergraduate research projects can be successfully incorporated into the Civil and Environmental Engineering (CEE) senior design program. These experimental, research-based projects expose students to undergraduate research, enable faculty to conduct research, and provide a means for industry sponsors to get valuable research done for their products. In this paper, we will discuss our experiences of having experimental, research-based senior design projects. Three different case studies will be presented, detailing how the projects were attained, the scope of the projects, and the publication of the undergraduate research in peer-reviewed publications. We will also discuss the overall response of faculty, students, and sponsors to these projects.

Seattle University and the Senior Design Program

SU is a primarily undergraduate institution with an approximate undergraduate enrollment of 4,000 students. The CEE department has an enrollment of around 80 students. Our students enjoy numerous civil and environmental engineering internship opportunities in the Seattle area. At the same time, most faculty at SU are interested in pursuing scholarly research. However, employing the undergraduate research assistants necessary to complete research programs is challenging due to students overwhelming desire and ability to have internships.

SU has a well-established, 20 year-old, industry-sponsored, senior capstone program, which is coordinated by the Science and Engineering Project Center. Senior design exposes students to real-world problems, while developing their analytical, project management, technical communication, teamwork, and design skills. Projects last for the entire academic year. Each team consists of three to

four students and is supervised by a liaison from the local sponsor agency and a faculty member. Most CEE projects are sponsored by local consulting companies and involve various aspects of civil design, such as structural, water resources, transportation, environmental, and site development.

Over the past 20 years, the CEE department has coordinated and advised 100 projects. Of these, 3 have been experimental, research-based. Project tasks are divided by quarter. Table 1 summarizes typical tasks that would be completed by consultant- and research- based projects during the three-quarter project. In general, the tasks are similar.

Table 1. Typical senior design team tasks by quarter for consultant - and research- based

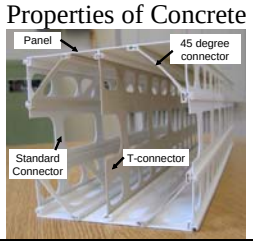
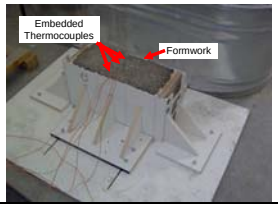
Project Type	**Fall Quarter** Proposal Preparation	**Winter Quarter**	**Spring Quarter** Final Report and Presentation
Consultant-Based	• Site evaluation • Applicable code research • Learn to use civil design software • Meet with client • Class presentations	• Perform design • Prepare drawings • Site visits • Meet with client • Class presentations	• Finish design components • Prepare final report and presentation for campus community and local industry • Present results to client
Experimental, research-based	• Plant, job site or laboratory visit • Literature review • Experimental design • Laboratory setup • Meet with client • Class presentations	• Conduct experimental program • Analyze data • Meet with client • Class presentations	• Complete experimental program and analysis • Prepare final report and presentation for campus community and local industry • Present results to client

Case Studies – Experimental, Research-Based Senior Design Projects

The CEE department has participated in three experimental, research-based projects. The general details of these projects are summarized in Table 2. Following is a detailed description of the three projects.

Table 2. Summary of experimental, research-based Projects

Project	**Sponsor**	**Research Objective**	**Result**
Construction Materials from Pulp Mill Solid Residuals – A feasibility Study 	Weyerhaeuser Company	Evaluate the use of three pulp mill wastes in construction: • hog fuel bottom ash • green liquor dregs • lime slaker grits	• Annual Padnos Undergraduate Design Competition Winner • Journal publication

Effect of PVC Stay-In-Place Formwork on the Mechanical Properties of Concrete 	Octaform Systems Inc.	Evaluate influence of PVC formwork on: • Flexural performance of reinforced and unreinforced beams • Compressive Strength	Journal submission
Effect of PVC Stay-In-Place Formwork on the Hydration of Concrete 	Octaform Systems Inc.	Evaluate influence of PVC formwork on hydration by examining effects of: • Wall thickness • Mix design • Insulation	In-progress

Construction Materials from Pulp Mill Solid Residuals

The first experimental, research-based senior design project was completed during the 1995-1996 academic year under the supervision of Prof. Gnanapragasam. The project was sponsored by Weyerhaeuser, an international forest product company, headquartered in Federal Way, Washington, which is close to SU. The project was titled "Construction Materials from Pulp-Mill Solid Residuals". Weyerhaeuser has sponsored several design projects at Seattle University. However, this was the first research-based project.

The objective of this project was to identify and demonstrate feasible uses in the construction industry for three pulp-mill solid residuals: hog fuel bottom ash, green liquor dregs, and lime slaker grits. These inorganic solid residual streams are generated in large quantities and are disposed of in landfills. Weyerhaeuser wanted the design team to investigate construction applications for these materials from a technical, economic, and environmental standpoint. The design team carried out a literature search on potential uses for these wastes. Based on the research, the team designed the experiments, planned a testing program, and executed it to test the suitability of these wastes in the use of controlled low strength materials, concrete products, bricks, artificial marble, and road base. The teams also interviewed local industries to gage their willingness to use these waste products in construction and reported their findings to Weyerhaeuser.

The project won the Grand prize award at the Annual Padnos Undergraduate design competition for environmentally responsible engineering design. The contest was sponsored by the American Society of Mechanical Engineers (ASME) and Grand Valley State University. The results were disseminated through a journal publication[7].

Effect of PVC Stay-In-Place Formwork on the Mechanical Properties of Concrete

During the 2005-2006 academic year, Prof. Kuder advised a senior design project titled "Effect of PVC Stay-In-Place Formwork on the Mechanical Properties of Concrete." This project was sponsored by Octaform Systems Inc., which is a company based in Vancouver, Canada that designs polyvinyl chloride (PVC) stay-in-place formwork. Octaform approached Seattle University interested in sponsoring an undergraduate research project due to the close proximity of the company to the university and the complimentary research background of Prof. Kuder.

The overall objective of the project was to characterize the effect of the stay-in-place formwork on the mechanical properties of the concrete that it encases. Mechanical testing included compression testing and flexural testing of unreinforced and reinforced concrete beams. The experimental design component of this project consisted of designing (1) the test fixtures for compression and flexural testing and (2) the steel reinforcement. To complete the testing fixtures, the students had to conduct a literature review on the existing research and testing standards available for flexural and compression testing. They then designed the fixtures, ordered the materials needed to construct them, and, finally, worked closely with the SU machinist to have the fixtures fabricated. Designing the steel reinforcement of the flexure beams included determining the size and location of tensile and shear reinforcement as well as developing a methodology for placing the steel. The students then cast and cured the concrete specimens, prepared them for testing, tested the specimens, and analyzed the data.

The research conducted in this project advanced the state-of-the-art of concrete technology. Stay-in-place formwork is still a relatively new technology and research on PVC formwork, in particular, is limited. With the support of an internal SU fellowship, the data obtained by the students was modeled by Prof. Kuder over the following summer. Subsequently, a journal submission was prepared and submitted with the students and the industry-sponsor as co-authors.

Effect of PVC Stay-In-Place Formwork on the Hydration of Concrete

Currently, Octaform Systems Inc. is sponsoring another senior design project (2006-2007 academic year). The objective of this project is to evaluate the effect of PVC stay-in-place formwork on the hydration of the concrete that it encases. The effect of the PVC formwork is being determined by comparing it with traditional formwork under a variety of construction variables, including wall thickness, concrete composition, and the use of insulation. This project involves practical considerations of how the concrete is placed in the field and also material science aspects of concrete as the relationship between temperature, hydration, and strength development are being evaluated.

The experimental design portion of this project consists of (1) designing formwork to simulate field conditions and (2) developing testing protocol for the evaluation of temperature and strength development. Designing the laboratory-scale formwork involved research current filed practices, designing possible formwork and working with SU carpenters on the completion of the final design. The students tested the heat development of basic cement mortar, interpreted the data and then selected mix designs based on their findings. In addition, extensive repeatability testing was performed to determine the testing protocol that should be used.

This project is still ongoing. Therefore, it is difficult to conclude how the work will be disseminated. Depending on the significance of the results, the work will be submitted to a peer-reviewed journal or presented at a technical conference.

Response of Students, Faculty, and Industry Sponsors

Overall, the response of students, faculty, and industry sponsors to experimental, experimental, research-based senior design projects has been positive. Students enjoy being exposed to projects that are different than the designs they participate in at work. In addition, students who are more hands-on, or visually oriented, are pleased to be able to work in the laboratory. Furthermore, students who want to learn about conducting research are able to do so without losing the benefits of having an outside internship.

Faculty also benefit from the opportunity to advise experimental, research-based senior design projects. These projects enable them to complete scholarly research by providing them with student research assistants, funding for necessary laboratory equipment and supplies, and time to devote to research. In addition, these projects can lead to strong collaborative opportunities between faculty and the industry sponsor, thus developing their scholarly research.

The response of industry sponsors to experimental, research-based senior design projects has also been extremely positive. Industry sponsors are able to get research completed on their products/design practices that would not otherwise be possible. The cost of these research projects is relatively small compared to what companies would need to pay to have independent laboratories perform the research. Projects also provide companies with a recruiting mechanism to find qualified students to hire after graduation, a prospect that is particularly appealing when it is difficult for companies to hire as many engineers as they need. Finally, company visibility is increased. Project sponsors are highlighted throughout the course of the academic year by the SU Project Center. Furthermore, faculty advisors are disseminating the results from the research at national and international levels. A testament to the success of these projects is the growing interest of other companies to sponsor experimental, research-based projects.

Lessons Learned

While many components of senior design projects are similar for consultant- and research- based projects, there are some main differences that are worthwhile to mention: (1) Experimental, research-based projects tend to be more expensive due to the research equipment and supplies needed. These differences should be accounted for when budgeting for the projects. (2) Research-based projects require technician support, appropriate lab facilities, and other infrastructure such as additional space. The university has to be helpful in building necessary laboratory facilities as well as providing technician support. (3) We have found that it is challenging for undergraduate students to conduct literature reviews without close guidance. This aspect of the project seems to run much more smoothly if the faculty advisor has already identified key literature and resources and has provided students with the basic project background. (4) Research projects require motivated students. Experimental projects require organized research plans, in which the students carefully plan their time. If the students merely rush through the laboratory work or wait until the last minute to complete experiments, the projects will not be successful.

Conclusion

Experimental, research-based senior designs projects can be successfully incorporated into senior design capstone programs. These projects expose students to undergraduate research, enable faculty to pursue research scholarship, and allow industry sponsors to get valuable research done for their products. At SU, we have found these projects to be quite successful, with the students, faculty and industry sponsors all benefiting.

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