AC 2008-1459: DEVELOPMENT OF A FRESHMAN AND PRE-FRESHMAN RESEARCH AND DESIGN PROGRAM IN ELECTRICAL ENGINEERING

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Abstract

It is well-known that involving students in activities and courses within their major early in their academic careers has a positive impact on student retention. We have developed several programs targeted at involving freshmen and pre-freshmen students in Electrical and Computer Engineering (ECE) projects. Teams of 4 to 5 students were formed, with at least one ECE freshman, a high school student (or recent graduate), a junior or senior level ECE student, and a community college student. Students were paid as interns for a six-week summer session. An industry or community mentor and an ECE faculty member were assigned to each team. Projects included: re-engineering an adaptive bicycle to enable use by a physically disabled child; designing a fall detector to automatically detect a fall in an elderly person; and, implementing smart sensors to measure energy and water use in a residential environment. Students were required to give weekly presentations to the faculty members and other teams in a formal setting. In assessing the success of the program in general and of each team's progress, several factors were determined to be significant. The presence of a strong peer role model and an active industry mentor influenced the level of involvement of each team member and the progress each team made toward achieving their project goals.

Introduction

This paper describes a program in the Electrical and Computer Engineering (ECE) Department at Texas Tech University that provides research and design opportunities for freshmen and pre-freshmen engineering students. The goal of the program was to increase recruitment and retention of students in ECE by exposing them to engineering through paid internships that focused on projects with social or community significance. The program was designed to address several key issues present when involving freshmen, high school, and community college students in engineering research and design. Among these: many students do not have a clear knowledge of what engineers do or of the engineering problem solving approach; faculty tend to be overwhelmed with the amount of time required to supervise very inexperienced students who have not amassed any technical knowledge or skills; and finally, students, particularly those from economically disadvantaged backgrounds, typically work and do not have the time to commit to summer or extended hour programs. These issues were addressed in various ways as the program was developed.

Pedagogical Background

The authors' motivations in developing this program were to increase engineering enrollment by bringing new students into the field and to improve student retention by exciting these students about engineering careers. Respondents to an ACT survey in 2004 reported by Habley[1] rated 24 institutional and 20 student characteristics for contribution to retention. They selected financial aid as the most significant institutional factor. Financial resources, poor motivation, job demands, and lack of educational aspirations and goals were cited as four of the most significant student factors. Ninety-one percent of campuses reported student internship activities of some form, with these activities considered to be important contributors to student retention. Swail[2] also notes that research opportunities are very beneficial to science and engineering students. Studying real-world applications of classroom concepts improves the student's educational experience and preparedness for the job market. Faculty-student contact beyond the classroom is also cited as helping to build student motivation and providing positive future impact on educational and career decisions[2]. Grabowski[3] also identifies success factors in undergraduate research that include 1) cross-disciplinary projects, 2) value both to students and to faculty, 3) close faculty mentoring, and 4) authentic rather than experiential activities. Such a program is identified with increased academic success and improved retention.

These freshman internship activities that this paper discusses address these factors, by providing financial support to students in activities that motivate them to seek engineering careers while removing other time-consuming employment demands. Employment experience within an academic environment positively addressed important retention factors in providing money, mentoring, and peer activities. Students developed specific technical expertise in the projects, thereby boosting their self-confidence. Interested students could also receive up to 6 hours of course credit while being paid competitive wages; most did so. Faculty and professional mentors met regularly with these students and encouraged their success.

Program Description

Project Teams

The program was structured around a six week, paid internship. Three teams of 4 to 5 students were formed. The students were supported through a grant from the Texas Engineering Technology Consortium – Texas Workforce Development Commission. Careful attention was given to the composition of each team. A junior or senior level engineering student was selected as the team leader for each team. The remaining students were taken from a pool of engineering freshmen, high school students, and community college students. Of the 13 students supported, two were in high school, three were recent high school graduates, two were from Midland Community College (an area community college), and seven were Texas Tech students. The three recent HS graduates were all accepted to Texas Tech to begin classes in the ensuing fall. Each team consisted of a high school student or recent graduate, a TTU freshman or Community College student, and a junior or senior electrical engineering student. In addition, each team had a faculty advisor from the ECE Department at TTU and an external industrial advisor or customer. The team composition was a key strategy in the program design. In a study comparing differences in design practices between freshmen and senior engineering students, Atman[4], et al., observed that senior students gathered more information and spent more time on final design phases than freshmen students. In the ECE department at TTU, students are exposed to a series of 5 project laboratories involving research and design. The junior and senior students who participated in this internship program had typically taken at least one of these project labs. The team composition thus exposed the more inexperienced team members to a more mature problem solving approach used by the experienced students. The peer mentoring that occurred between the team leaders and the team members was a strong component of the program. Additionally, the peer mentoring and inclusion of junior and senior students on the teams made it much easier for the faculty advisors to interact with the teams, as these students could communicate effectively with both the faculty member and the younger team members. There have been programs by other educators that demonstrated the effectiveness of peer mentoring programs and undergraduate research. Elsegood[5], et. al. reported that students who served as peer mentors were very attractive to potential employers, while students who were mentored were more likely to be retained in programs. The Boyer Commission report[6] emphasizes the importance of undergraduate research, mentoring, and an inquiry-based freshman year as a critical components in undergraduate education.

Project Selection

The projects chosen for the teams were selected to have some social, community, or environmental relevance. This focus was selected to demonstrate to young potential engineers that the field of engineering is not just mathematics and science but has a direct impact on quality of life issues. We selected three specific projects: integration of sensors to measure water and electricity usage within a “smart” house; automatic detection of falls occurring in the elderly populations and associated automatic alert system; and construction of an adaptive three-wheeled bicycle for children with disabilities. Several factors were taken into consideration in the selection of project topics and in the writing of problem statements.

- Projects must have some element of construction or assembly of a prototype, and this prototype should be built from available, off the shelf components.
- Some aspect of measurement or data acquisition was present in each project, allowing students to acquire data for multiple trials and compute averages and standard deviations, as well as vary conditions and observe effects.
- All projects involved some aspect of computation, either computer based modeling, data acquisition, or data analysis.

The selection and design of projects allowed students to be exposed to measurement techniques and standard computer tools such as Matlab and Labview. Each team had a community mentor or customer. In the case of the “smart house” team, an engineer from a local consulting company committed to serve as a mentor, but never met with the team due to scheduling conflicts. The fall detection team had a mentor from the Garrison Institute for Aging, who met with the team in the early planning phases and discussed practical aspects of design and implementation. This team visited a senior citizens center, but did not have a clearly identified customer. The adaptive bicycle team had a mentor from out of state that serves on the TTU ECE Industrial Advisory Board and is an avid cyclist. This mentor met personally with the team at the beginning and at the end of the project, and communicated via telephone and e-mail on numerous occasions. This team also had a specific customer, a disabled child, who met with the team, communicated her needs, and later evaluated the final result. Each team had a budget of approximately $1000 for supplies and components and was encouraged to stay within their budget. High school students were paid $7.50 per hour; community college and university students were paid $10.00 per hour. All students were allowed to work up to 40 hours per week for six weeks. Several students opted to work fewer hours in order to take a summer school course during their time on campus. The cost per team of 4 students, including student salaries and supplies, was less than $10,000.

Project Management

Each team was assigned a junior or senior engineering student who coordinated the teams' efforts. The teams and the three faculty advisors met as a group weekly, and each team gave a formal oral presentation of their work. Teams were required to create a clear problem statement, project objectives, and project budget and plan. Gantt charts were used as a tool to track the project budget and schedule. The presentations were team presentations, but each student was required to give a portion of the presentation describing some aspect of his or her work over the past week. An example of a sample budget, as presented by one of the teams, is shown in Figure 1. Professionalism by both the presenters and the audience was strongly emphasized and encouraged during these presentations. Students were encouraged to ask questions and offer suggestions to other teams during this time. The faculty advisors were present to offer technical input and critique oral presentations.

Figure 1 Sample Equipment and Supplies Budget as Presented by Students

Remote Panic Button	$23.99
Emergency Dialer	$119.99
Analog Accelerometer	
Wireless Accelerometer/Tilt Controller Version 2.5	$109.95
Bluetooth Dongle and Soleil Software	$16.95
Belkin Bluetooth Adapter	$39.99
Battery Holder	$7.00
Total	***$317.87***

Program Outcomes and Results

Project Results

Each team managed to obtain some version of a working product as a result of the summer internship program. The fall detection team used a prefabricated accelerometer board with wireless capabilities to acquire data of typical walking and falling patterns. The team worked with a martial arts instructor to obtain data on falls. The data were acquired and loaded into Matlab for presentation purposes. This team did not perform any significant analysis of the signals that they obtained as a result of their testing. The smart house team integrated water flow and electric power sensors into a Labview environment. The team managed to obtain the sensors and to characterize them. A Labview user interface was developed. The team made some progress in integrating the sensors with the Labview interface. The adaptive bicycle team was successful in modifying a three-wheeled bicycle/tricycle mechanically to accommodate the customer. They also integrated a motor that could be activated should the rider become too fatigued to continue and a remote control brake system that could be initiated by a third-party observer.

The teams and their progress were continuously evaluated by the faculty mentors who were involved in the program. Several struggles were common among students in all teams. The students had difficulty getting started on their projects – even making decisions on what types of parts to order was difficult for the inexperienced students. One team in particular got stuck in analyzing the problem as opposed to making a decision on a specific approach and ordering components. Another common struggle was one of practicality of design and measurement. For example, the adaptive bicycle team was told to integrate remote control braking. The initial remote control that they implemented was from a remote car locking system, and had a range of only about 20 feet. Considering that the motor on the bicycle could achieve speeds of 20 miles per hour, the range of the remote control would only allow braking during the first few seconds before the rider was out of range. Another example concerned the water flow measurement by the smart house team. They were told to develop a sensor system that would detect small drips or leaks within a residential plumbing system. The flow systems that they developed measured flow rates typical of a fully running faucet. Even the more senior students failed to make the connection between the selected sensors or controllers and the practical goals of the projects. This lack of connection served as one of the most valuable learning experiences for the students (and the faculty, who did not anticipate this problem).

Project Components That Worked Well

The bicycle team had significantly closer interaction with both their industrial mentor and their customer, and that team did a notably better job in meeting the project requirements. The team found that a specific name and face in mind kept them focused on producing a bicycle that would not disappoint her. The industrial mentor had excellent advice to offer, and the team realized and exploited the value of that resource. The team leader quickly realized that his primary role was leadership, and the younger students readily fell into line because they realized that the team goals would be best served with teamwork. The final product is shown in Figure 2.

Figure 2 Adapted Bicycle

The smart house team organized itself behind its team leader a few days after the bicycle team. As soon as the team leader observed the leadership component in action in the other group, he quickly adjusted his role as well, and this team was also well led and productive. While the lack of specific customer made actualization more difficult for them to visualize, the team did achieve their main goals.

Project Components That Did Not Work Well

The fall detection team did not get itself organized as well as other teams. The junior student team leader did not take a leadership role. It is likely that she did not truly understand that the leadership and planning role was her responsibility. This group found itself in perpetual quest for consensus, which it could not achieve. This team did not have a specific name and face to visualize as their customer, and this factor made practical solutions difficult for them to visualize. The community mentor was fully aware of what his elderly clients required, but she was not technically knowledgeable enough to guide the team through the required decisions. Design problems have an infinite number of potential solutions; making decisions that reduce a project to realizable dimensions is necessary. Unfortunately, this group did not achieve an adequate level of maturity, and the faculty member was forced to make many decisions for them so that they could achieve some progress. Despite the fact that this group encountered some leadership problems, they still functioned well enough to acquire data from the accelerometer based fall detector and to incorporate this into a final presentation, as shown in Figures 3 and 4. The group also presented a final budget and Gantt chart as a part of their final presentation.

Figure 3 Accelerometer Output for Fall Detection

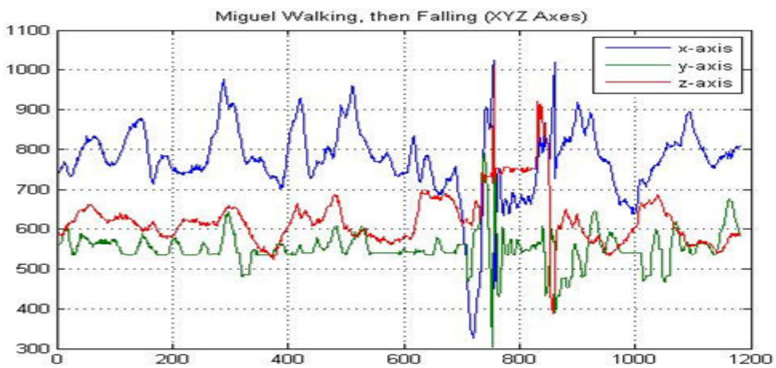

Figure 4 Testing the Fall Detection in the Laboratory (see subject’s wrist)

Student Questionnaire Responses

The students who participated in the program were given a short questionnaire at the beginning of the program to assess their level of education and experience and to determine their reasons for participating in the program. Of the seven students who attended high school in the US and did not have any engineering courses at Texas Tech, four had completed calculus in high school, two were on track to complete calculus in their senior year, one completed pre-calculus, and three had some experience in programming C++. When asked what attracted them to engineering, students typically responded with one of three statements – an interest in math and science, an interest in building things, or a strong influence by a family member or teacher. Several students had attended a summer camp that gave them some exposure to engineering and mentioned that experience as well.

Students were also given a questionnaire at the end of the summer experience. Of the seven students who were not peer mentors and responded to the survey, all of the students responded that the experience had influenced their opinion about electrical and computer engineering as a career choice, six in a positive way, and one who decided that ECE was not a career choice. Students were asked to evaluate several components of the program on a scale of 1 to 5, with 1 being "not at all helpful" and 5 being "very helpful". The average scores for student responses to this evaluation are given in Table 1.

Table 1

Program Component	Response
Project Assignment and Selection	4.0
Weekly Presentations	3.9
Senior Lab Student Presentation Attendance and Observation	3.5
Introductory Remarks and Seminar by Faculty	4.4
Student Team Leader	4.6
Departmental Resources (stockroom, computer room, lab)	4.8
Fellow Team Members	3.9
Use of Gantt charts	3.8
External Mentors/Sponsors	3.4

Students were also asked to evaluate on a scale of 1(strongly disagree) to 5 (strongly agree) the statements shown in Table 2. The average student response is shown in the table.

Table 2

Statement	Response
I know much more about the field of engineering than I did before this experience.	3.5
I feel more confident in my abilities to succeed in engineering after this internship.	4.0
I understand more about aspects of time and project management.	4.1
I understand more about the engineering problem solving approach and critical thinking.	4.5

Suggestions for Effective Program Implementation and Conclusions

The overall experience of both students and faculty involved in this program was extremely positive. As a result of lessons learned from observing student performance over the summer, the authors have compiled of list of factors that are important in guaranteeing a successful freshman and pre-freshman research/design experience:

- It is important that the students are financially supported at some level throughout the internship experience. This increases diversity of the student pool and addresses the issues associated with students who need to work during the summer.
- The team approach is very effective and boosts students' confidence. Students expressed strong satisfaction with working in teams.
- Choosing an effective team leader is crucial to the success of the team in developing a working product. The leader should be technically competent, but more important, should be self-confident enough to guide the team in making steady progress.
- Selection of appropriate projects is also important. Choosing project goals that can be accomplished in a reasonable amount of time and result in a completed project is more important than selecting projects for specific technical content.
- Involvement of a customer or client creates additional motivation for the students to perform. A customer *needs* the product, as opposed to a mentor or advisor who simply evaluates the team's performance.

In conclusion, the implementation of this program proved beneficial to the students involved, both those students who acted as leaders, and those who were team members and were exposed to engineering for the first time. The involvement of industry or community mentors was mixed. It worked very well when the individual mentor was invested in the project; otherwise, the mentors were too busy to spend enough time with the students. The faculty mentors had positive experiences interacting with the students. It was particularly helpful to the faculty to have junior and senior engineering students acting as supervisors/mentors for the less experienced students.

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