AC 2007-2738: STUDENTS AND FACULTY EXPERIENCES IN TECHNOLOGY AND ENGINEERING WORKSHOPS FOR MIDDLE AND HIGH SCHOOLS

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Engineering and Technology Experiences in Workshops for High and Middle School Students

Abstract

Activities focusing on introducing engineering and technology to students in high and middle school are taken place at our institutions. These activities have developed into one- or two-day workshops and consecutive-days residential institutes. The main goal of all these activities is to plant the seed about technology and engineering in the minds of the young participants. Therefore, a variety of sessions take place in order to show them new technical concepts and to challenge them to make use of those concepts. For the high-school students, the activities during the residential institutes are in the context of emulating a typical design process in industry, from concept to prototype. This product development process is valuable because it corresponds with the type of interpersonal communication, problem-solving, and conflict resolution skills that leading firms and industry seek from new employees. For the participants from middle schools, the several-days workshops have activities that expose them to technology in the short workshops, and introduction and use of technical concepts (via use of Lego sets) for the longer workshops, with emphasis on the design process as well.

For both groups, the students are assigned interactive projects that stimulate imagination and creativity incorporating hands-on science, technology and computer programming concepts. Appropriate design challenges are given to the students so that emphasis is not only on engineering and computer programming concepts but also on experimentation and teamwork while having fun. The paper will discuss the experiences by the authors, in a period of two years, when carrying out these activities at our institutions; together with the opinion by the high school students attending the institutes. Discussion on the selection process and the group dynamics during the workshops will be discussed as well. Given current trends in enrollments at our institutions and the fact that most of the budget for these activities is coming from state agencies, the eventual effect of these activities as recruitment activities will be discussed as well.

Introduction

The United States of America is a country that thrives on technological advancement. We have an insatiable appetite for the latest technology and do not mind spending billions of dollars each year to satisfy our yearnings. Unfortunately, we are not as passionate about encouraging our youth to pursue careers in engineering and technology. The gap between the demand for engineers and the supply required by industry is growing and is not being filled by our own talent pool[1]. The problem of attracting students to engineering has been a topic largely debated. The most commonly cited reasons for the limited interest by students is an undeniable image problem[2] ("Engineers are the *guys* who carry pocket protectors and wear black rimed glasses, the *guys* who love math and science – you know, geeks of the world") and a lack of understanding about what a career in engineering and technology may entail[3]. As stated by Mike Eby[2]: "Most kids worship athletes, rock stars, or actors. Some even look up to fireman, policemen, and doctors. But when was the last time you heard a kid say, "I want to be an engineer when I grow up!"?. These realities are even worst when we look at statistics focusing on enrollment in STEM disciplines by minorities.

It is for these very reasons that our institutions (Western Michigan University and University of Wisconsin-Waukesha) in conjunction with State agencies, and some partnership with industry have created institutes and workshops designed to energize students about a possible career in engineering or technology. We call "institutes" a residential program, with one or two weeks of activities; and workshops will be the non-residential programs that could go from one day to five days-week being the complete program, but different activities from the general institute can be taken and implemented as a program for young students. The programs can run from one to five days. Basically institutes are offered to high-school students, and workshops are offered to middle school students.

For the several-day programs, the general theme is entitled "Design-Engineering-Technology: Enlightened Trial and Error" and have been offered as one-week and two-week summer program. The program is an intensive learning experience, particularly if all the components are offered in a one-week session. The basis is to have a simulated engineering product development environment, and it is for juniors and seniors. It provides an interdisciplinary program for students that involve various aspects of design process, ergonomics, engineering and technology, and business management. The goal of this program is to give students an opportunity to interact with engineering professionals and practitioners in a simulated engineering product design process. This product development process is valuable because it corresponds with the type of interpersonal communication, problem-solving, and conflict resolution skills that leading firms and industry seek from new employees.

Program

By involving students in an innovative approach to product design and allowing students to experience elements of an engineering design environment, it is thought that their interest in engineering as a future career will increase. Institute and workshop students discover how imagination, creativity, technology, and engineering tools combine to turn their ideas into reality. Active learning in a collaborative, discovery-oriented design environment that involves students in a competitive, real-world type of project provides the opportunity for the students to acquire and/or apply multiple talents and skills. The students are constantly challenged during the programs as they conceptualize and plan a product or system, develop models, build prototypes, evaluate and redesign their product, and present a finished product prototype and marketing strategy to the "contracting company" (i.e., industry people, Institute participants and parents).

For both, the institute and the long workshops, the design philosophy emphasized is the Design-Redesign iterative sequence. Students are guided through a complete design sequence, starting with problem definition, and ending up with prototype building and testing. Particular attention is given to the conceptual design stage, where students need to establish the goals for the project, brainstorm for solutions, and evaluate concepts. For the residential program the task has been to design a new shopping cart for supermarkets. This has been a good project to pursue because it allows for prototyping building by students, without the need of specialized skills.

For the short workshops, because typically they are for middle (and even elementary) school students, the program is more direct in introducing few concepts that will be emphasized with hands-on activities the same day. Quick, fun activities like "modified" spaghetti bridge construction, balsawood airplane model construction, roller coaster design and CAD software projects are in the portfolio. These are activities are modified in order to have a new challenge for them, so that it is not a repetition of something that the students might have done already.

Participants. Students are selected according to the focus of the program. For high school institutes, students in the 10th or 11th grade receive the information and the materials from their school guidance counselor. Middle school long (summer) workshops are for students in the 6^{th} to 8^{th} grades. Short workshops are special arrangement between teachers and the universities.

The applicants to the long programs need to submit the application form together with a letter of nomination and recommendation. It has been always the case that we have more applicants than places (budget). Special efforts go into trying to have a diverse (race, gender, geographic) participant body. Another document that they need to submit is an essay stating their interest, talents, and abilities related to science, arts, and technology. For the institute at WMU we have been able to accommodate 24 and 36 students in the two initial offerings of the institute, with 53% of the participants to be from underrepresented groups, mainly female and ethnic minorities. For the program at UWW, in the past two years there has been a total of seven week-long workshops with a total of 74 participants.

Instructors. At WMU there are three faculty members from the College of Engineering leading the programs. These faculty members have expertise in industrial engineering, computer-aided design/manufacturing, statistics, optimization, ergonomics, and business management. They also have extensive experience working with high school students, as advisors or as recruiters. Additionally, there is a designer/engineer from IDEO who serves as institute instructor. For the workshops at UWW, one faculty member is completely responsible of the program. In both cases there are several other faculty, staff or college students participating in the logistics and technical activities.

Activities. In all activities students work in teams, there is no main activity where a student work bi her/himself. In the long programs the element of competition is as well included. In the institutes students are divided into three design firm teams, each one led by one of the three institute faculty members. The instructors form the teams after observing the participants for a day of activities. The intention was to have as balanced teams as possible in terms of personalities and skills. Each student has ample opportunities to contribute to problem-solving team efforts as they design and develop their product. Students participate in collaborative learning sessions about the design process, data collection from potential customers, and tasks to accomplish their goals that result in the manufacture of their prototype. Recognizing that students need to occasionally take a break from the intensive product design process, the instructors have also included "design challenges" that allow students to puzzle over a challenging problem for a short period of time (the teams in this challenges are different from the Design teams). For the residential programs, time is allocated for the students to interact with each other in peer evening group sessions in order to reflect on the activities of the day, address issues of concern, and focus on a topic of interest for high school students planning to be college students. The program has also included a variety of social and recreational activities, such as museum tours, baseball games, swimming, laser tag, and beach picnics.

Evaluation

For the institute , a survey adapted from one used by the State in other programs was adapted to include all the activities that a complete institute would have. Thus, investigating students' perceptions of instructor competency, personal growth in knowledge, interactions with instructors and peers, and their general experience of and reaction to institute activities. In general, the questionnaire responses indicated that most of the students had a high degree of satisfaction with what they learned and experienced through their design institute, including the class sessions, special challenge projects, and social activities. Students reported that they enjoyed interacting with peers, their team members, and the faculty. As a result, faculty were confident in their process and their ability to conduct a beneficial program that provided students a rich learning experience and positive exposure to engineering and technology.

Other questions that concerned the more intermediate and long-term outcomes of the program became the focus of further evaluation. For example, the faculty wanted to know the impact of the institute upon students' choice of college and major field of study. The engineering professors also wanted to know the impact of the institute upon participants' perceptions of engineering as a profession, their plans to pursue engineering as a career choice, and their perceptions of these universities as a potential school for studying engineering. For this endeavor, the following evaluation questions were posed:

1. *What are participants' beliefs about engineering?*
    - *How have participants' beliefs about engineering changed over the Institute?*
2. *What are participants' beliefs about a career in engineering?*
    - *How have participants' beliefs about engineering as a career changed over the Institute?*

Methodology

A pre/post survey instrument was designed in order to track changes in participants' beliefs about engineering over time, from the beginning of the Institute to the completion of the Institute. Changes in participants' responses may indicate changes in their perceptions about engineering or engineering as a career. Furthermore, the pre-survey contains only a portion of the complete set of attitudinal items (approximately 30 items), while the post-survey contains all items (approximately 40 items). This is to mitigate data contamination through participant memory of items from the pre-survey. Because of the short amount of time incurred between survey administrations, participants may respond to the survey items based on memory rather than actual changes in attitude. New items in the post-survey offer a broader spectrum of data that mitigate the effect of participant memory.

The survey was adapted from an attitudinal survey designed for high school students to assess their beliefs about engineering[4]. The original survey was tested for both reliability and validity through pilot testing and statistical analysis. The survey was modified, however, to add more items about beliefs about engineering and to include items to assess participants' perceptions of engineering as a career. The survey addresses participants' beliefs about engineering, especially perceptions about teamwork, creativity, and sociability in engineering as a field. Although not reported in this paper, the survey also addresses Institute participants' perceptions about the quality of the engineering program at these universities as well as campus life at the university campus, and cultural life in our cities.

The survey is largely designed as a quantitative evaluation tool[5]. Quantitative survey items are scaled on a six-point scale from Very Strongly Disagree (1) to Very Strongly Agree (6). Survey items were written in both the positive and negative format (e.g., I think…, I do not think…) in order to increase the reliability of the scale. This helps prevent habitual responses from participants who tend to mark the same response for all survey items. Several qualitative, open-ended questions that invite participants to write lengthier responses were also added to give more depth and insight to the quantitative attitudinal data. Open-ended questions in the pre-survey address participants' motivations to attend the Institute and expectations for the Institute while open-ended questions on the post-survey address participants' learning from the Institute and suggestions for improvement.

Results

Based on the analysis (t-tests) of the data collected, it can be said that in general the participants' (as a whole) perceptions of engineers and engineering were significantly influenced in a positive manner. We believe that the image of "the *guys* who carry pocket protectors and wear black rimed glasses, the guys who love math and science – you know, geeks of the world" has been successfully eradicated from the participants by having 5 of the 6 factors (Table 1) selected to show significant difference. It is felt that the combination of faculty mentoring and the participation of engineering faculty, practitioners, and engineering staff (host undergraduate and graduate engineering students) in non-engineering events has passively allowed students to observe the other side of engineering in a very positive light. Furthermore the student employees[6] who helped us facilitate this Institute were selected because they, as well, were passionate about their impending career choice. It is inevitable that high school students left the Institute excited about the prospects of a career in engineering and college in general. Although the survey did not indicate a significant difference in the pre/post response of the participants' perceptions on engineering as a career (it shows significance when the monetary factor is included), the mean score was 5.1 out of 6.0 and would seem to indicate that a good portion of the group is considering engineering as a career.

One of the most exciting findings from the survey was that we were able to significantly influence the female students perceptions of engineers[7], as well as their potential for a career in this area. Besides the insights stated in the last paragraph about mentoring and viewing the human side of engineers, it is believed that our selection of student staff aided greatly in this success. Six out of the ten student facilitators were women in our engineering program, a higher percentage than in the engineering majors (21%). Inevitably, even though they were only assigned support responsibilities, they became role models and clearly demonstrated effective leadership to all the students. All these issues, coupled with one-on-one mentoring session by all staff members had a positive effect on the participants. In terms of the change in perceptions of the minority population in general we are encouraged. Although the statistics do not discern a statistical improvement (besides women as a group), the trends are pointed in the right direction. Undoubtedly, some of these students will pursue careers in this area.

Table 1. Factors (question) for t-test.

Perceptions of engineers or engineering
Engineers spend most of their time doing complex mathematical calculations
Engineers deal primarily with theory
A problem with engineering is that engineers seldom get to do anything practical
Most skills learned in engineering would be useful in everyday life
Engineers need a great deal of natural ability for science and mathematics
Engineers spend most of their time working in offices
Perceptions of engineering as a career
Engineering would be a highly interesting career for me
A career in engineering would be highly financially rewarding

Conclusions

These activities with high school and middle school students have various objectives, where recruitment being one of the most important ones. Based on the data it can be said that the programs offered at our universities have had a significant positive impact on the perception that high schools students have about engineering. The pre/post surveys indicate that there has been a shift in beliefs and thoughts about a career in engineering for the groups as a whole. This impact was more pronounced among female participants, which was of great satisfaction for the faculty involved. The long-term effects of the Institute are partially known at this point, but for the first group of students it was found that a high percentage (88%) did pursued a college education in the technical field, with some of those students coming to the host institution. Given such success, funding is being sought to continue these activities

Similarly, it has been proven to be critical to keep presentation of concepts brief and dynamic (reason for the design challenges). The activities are designed to be fun and instructive. Students report almost 100% satisfaction with activities and some sign for additional sessions.

In summer 2007 better information will be available from previous workshops and institute; unfortunately there are only three workshops programmed for this year.

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