The Business of Engineering: Sharing Lessons on Motivating Potential Future Engineers

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Abstract – This paper reports on a unique approach incorporating engineering and business concepts in pre-college engineering. The report draws on the findings of exposing and motivating high performing minority high school students to engineering. Hampton University piloted a 3-year (2007-09) summer academic enrichment program aimed at (1) demonstrating interdependence of engineering and business in making real world choices, (2) engineering methodology as a means of problem solving, (3) exposing students to the entertaining, yet challenging world of engineering, (4) introducing students to cutting edge, computer-aided design software used to solve day-to-day problems, and (5) teaching students teamwork skills. The motivation and model of the business of engineering approach is presented. Outcomes of the pilot program implementing the approach are shared.

Keywords: pre-college, business and engineering, minority

BACKGROUND

Engineering students at any level are successful in their crafts if they are engaged in the subject matter of their interest [Chen, 3][Chubin, 5][Ohland, 9]. Engagement is possible through a variety of methods such as hands-on-experience, teamwork, and technology integration. Engineering programs along with private and government agencies are interested in training a future engineering workforce that is highly motivated, qualified, and representative of population demographics.

Research shows that 34% of the United States population are minority groups, but only half of minorities are represented in the engineering and science workforce [Anonymous, 1][Christie, 4]. Although a significant number of minorities are enrolled in higher education, there are also some perceived barriers as to why only a few choose to study and work in engineering. The barriers include a lack of availability of accurate career information that reflects the real work of engineers in many different settings. Therefore, greater involvement in education at all levels especially K-12 is advocated for engineers [Malcolm, 7]. The pathways of becoming an engineer are attributed to factors such as knowledge of engineering prior to college matriculation, motivation to study engineering, and perception of needed knowledge and skills among others [Chubin, 5]. The introduction of engineering in pre-college has been generally delivered to students as a stand-alone subject or as a subject integrated with mathematics and science as substantiated by the number of existing pre-college programs around the nation [Brophy, 2][Chubin, 5][Johnson, 6][Rivoli, 11]. Most of the existing programs have been successfully evaluated to show that they engage students; however, outcomes on other professional experiences and degree attainment have not been well evaluated. For example, preparing for a successful career in engineering involves the development of skills needed in project management [Nicholas, 8]. Business and engineering schools are incorporating training to prepare future leaders for the integration of the technical and the human side of product development. The business skills needed as a project manager are an integral part of delivering a quality product to a customer. Such skills include management,

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leadership, and the integration of other aspects of business processes. Furthermore, the profitability of technical projects requires an understanding of business concepts.

The Leadership Education and Development (LEAD) program has been addressing business training through pre-college business programs since 1980 [Ramsey, 10]. LEAD was created by leaders in industry and academia as an innovative and intensive summer business program for high school juniors after recognizing that a lack of role models in business was discouraging students from underrepresented communities from pursuing business careers. The Business of Engineering program was initiated based on the need to motivate minority students to participate in engineering and the analysis of LEAD alumni high school graduation statistics, which showed engineering as the second most popular college major chosen by LEAD alumni. Given the data, it appeared that many LEAD students were interested in learning more about engineering. More importantly, it was discovered that a large percentage of LEAD alumni worked with engineers at some point in their career, so being exposed to what engineers do was beneficial to their future career.

Recognizing the importance of exposing students to the business of engineering, Hampton University has held a one-week summer academic enrichment program for high school students in collaboration with LEAD since 2007. For the past three summers, Hampton University has offered a series of interactive workshops, which provided students an opportunity to learn more about the world of engineering within an intellectually stimulating environment. Objectives of the program are as follows:

1. To demonstrate interdependence of engineering and business in making real world choices, and
2. To introduce engineering methodology as a means of problem solving.
3. To expose students to the entertaining, yet challenging world of engineering.
4. To introduce students to cutting edge, computer-aided design software used to solve day-to-day problems.
5. To develop teamwork skills

Specifically the program engaged students in problem solving, and hands-on experience. Students participated in design contests, case studies, and educational field trips. Program participants also worked in teams on a week-long design study and presented their findings at the end of the week. The business of engineering students were also surveyed on their post-program impression of and knowledge about engineering including potential career choices.

BUSINESS OF ENGINEERING APPROACH

In 2007 and 2008 the Business of Engineering students were rising senior high school students, and in 2009 rising 10^{th} graders were the participants. The shift to 10^{th} graders was initiated by the need to reach students who have not yet made their decisions about college. In each year, undergraduate students in the fields of business and engineering were engaged to assist as program counselors. The program offered several perspectives from business professionals and engineers and focused on the case study based on local transportation challenges. The technical approach in the implementation of the business of engineering program is summarized through activities used to engage the students. For the period of one week, the business of engineering students were engaged in engineering-based projects that involved theoretical and practical problem solving as well as presentations and discussions on business decisions and engineering problems and solutions in their daily lives. The activities were broken down into workshops, field trips, design contests and the main case study project that fostered teamwork and development of communication skills among the participants.

Workshops

The students were engaged in workshops conducted by professionals in the fields of engineering and business. The workshops' subject matter and main objectives were: to introduce engineering and the interdependence of engineering and business to the participants, and to prepare them for design contests as well as the design case study. The goal of each workshop was to both motivate and inform. Different presenters introduced students to a range of personalities and interests involved in the exciting world of engineering. Over the three years of the program, workshop presenters came mainly from Hampton University's engineering and business departments, DOE's Jefferson Lab, Northrop Grumman, Nucor, and NASA Langley. Some workshops were on engineering fundamentals, problem solving and applications in everyday life, and introduction to hands-on engineering tools. One workshop was a roundtable of business and engineering professionals discussing with students about their careers and what they do in everyday life to help students in understanding the engineering profession. In general the workshops addressed aspects of all the program objectives.

Field Trips

Students participated in two entertaining and educational trips. The students visited the Virginia Air and Space Museum, located in Hampton, as well as the Busch Gardens amusement park in Williamsburg, Virginia. In the airspace museum, students got the opportunity to learn about aerospace engineering and aviation history as well as the engineering aspects that support commercial and military aviation. In each trip, the students had to complete activity exercises related to business and engineering concepts. The field trips afforded students the opportunity to realize the fun and entertaining side of engineering or what we call engineering design for fun.

Design Contests

Design contests were held mainly on evenings during the week. These contests were intended to give the participants a chance to see how engineers solve design problems, have fun, and see how their peers come up with different solutions to the same open-ended problems. Contests involved business-engineering applications. The Computer Aided Design (CAD) contest involved using the West Point Bridge Designer tool to design and load test a bridge given certain specifications. The students tinkered with different construction material and design templates as well as the cost associated with the construction of the bridge. The CAD contest served as a primer to the prototype bridge building exercise that the students worked on as well as the case study project. Bridge building was a team exercise where students were given material such as wood sticks, tape, glue, wood cutters, and rulers to design, build and load test a prototype bridge. The rules were that the bridge had to have minimum dimensions of 30cm by 10cm and sustain loads of up to 40 pounds. In addition to the load, the bridge was also evaluated on the proportional dollar cost of the material used, whether it was a practical solution, its appearance, and complexity.

Another exercise was an egg-drop design contest that involved sorting through different set of resources and trading with the groups that had different resources to add value to the product during design. Each team was given base material and credit points to build the egg drop device as well as unique material that could be barter traded for other material unique to other teams or bought from the resource center. Each team had to decide what material they will use to design and build the egg drop device and program counselors were responsible to keep track of spending. Finally, after the product was built, the best design was awarded based on the design that best protected the eggs during tests. Each team was allowed to perform multiple egg drops, until the egg broke. Each team was rewarded with the amount of credits equal to 100 times the number of successful drops. The design criteria was also in such a way that the egg was easily accessible because each team was allow about 5 minutes to check their egg after a drop, make any repairs/adjustments, and be ready for subsequent drop. Each design contest was first explained for context. For example, the egg drop design contest has applications in parachute technology and dropping care packages safely in disaster areas without the necessity for risk of landing airplanes. The design contests also emphasized the objectives on teamwork and the use of computer tools to solve problems.

Design Case Study

Figure 1: Satellite image of Hampton Roads Metropolitan Area

The Hampton Roads Metropolitan Area shown in Figure 1 consists of seven cities, most separated by water. North

of the Hampton Roads waterway are Hampton and Newport News and south of the waterway are Chesapeake, Norfolk, Portsmouth, Suffolk, and Virginia Beach.

Daily commuting and general transportation between the north and south sides is heavy and limited to water crossings, so traffic is a key concern for everyday life as well as for evacuation situations. The crossing options are complicated by the fact that the port of Norfolk is a major commercial port and that there are major Navy and shipbuilding facilities in the area. At present, there are three crossings, two bridge-tunnels and one bridge. Ferry service was discontinued years ago.

Students in *The Business of Engineering* program were given a design case study challenge of selecting the Hampton Roads transportation project that will best address current and future regional traffic needs. Students working in teams presented their solutions while considering multi-modal options for the crossing, such as bus ways, high-occupancy vehicles (HOV), and passenger rail. Their solutions focused on designs addressing the environment, tourism industry, daily commuting, and commercial shipping business impacts. Workshop sessions during the week provided the students with the key content to assist in their study. Team solutions considered both technical and economic factors in making recommendations. Since one of the crossings, the Hampton Roads Bridge Tunnel is in sight of Hampton University, students were able to make some traffic observations of their own.

CURRENT OUTCOMES

The Business of Engineering at Hampton University has hosted 52 highly talented high school students from different parts of the country. Over a period of three summers (2007 – 18 students; 2008 – 17 students; and 2009 – 17 students), students were immersed in an intense one-week on-campus program involving engineering projects intertwined with business practice. Both parents and students provided valuable feedback regarding the program. Students were asked important aspects of the program such as the relevance to career choice, program content, and program logistics were used to evaluate the impact of the program. Table 1 gives a summary of the feedback from students based on exit surveys. Each year students were asked to evaluate the program sessions and activities on a scale of 1 (poor) to 5 (excellent) and on similar scale on how relevant the sessions were to their career choices.

Table 1: 2007-09 Survey results

Activity	Session Rating			Career Relevancy		
	2007	**2008**	**2009**	**2007**	**2008**	**2009**
Workshops	3.90	3.94	3.89	3.40	3.70	3.75
Design Contests	4.15	4.53	4.18	3.45	3.33	3.54
Field Trips	4.15	4.52	4.92	3.40	3.33	2.78
Case Study Project	4.00	3.88	4.20	3.90	3.27	3.47

Each year more than 90% of the participants said they would recommend the program to other students. Other than field trips, the students rated the workshops, design contests, and project presentations as better than average. In 2009, nearly 60% rated the overall program as "excellent" and the remaining 40% rated the program as "better than average". In 2007 20% of the participants surveyed viewed the overall program as very relevant to their career choice. In 2009 that number rose to 40%. One reason for this significant change is attributed to the reconsideration of the grade level of participants. In 2007 and 2008 the focus was on rising high school seniors, however, in 2009 the program engaged rising 10^{th} graders. It is possible the program is more relevant to students who are not close to graduation since high school seniors are more likely to have already made their career decision. It is also noticeable that the field trip sessions were well received by the students, but they considered them less relevant to their career choices compared to other activities and this could be attributed to the fact that the younger participants were still undecided on their careers. The challenge is to bridge the gap between activities that get students motivated and their career choices.

Open remarks by students and parents were also beneficial in learning about the program outcomes.

Sample remarks from student participants included:

- "Thank you for providing such a great program. I look forward to recommending it to some of my friends";
- "It was a great opportunity to meet new people, learn about leadership, and experience challenges."
- "it is fun, you meet new people, and have fun."
- "What I enjoyed the most, is the CAD demonstration"
- "…getting hands on experience on projects … helped me learn about the engineering aspects of building structures while also having fun."
- "..competition made me work so hard in my group and it kept me active."
- "The projects showed how group members would be able to come together as one and solve the problem as one."

Sample remarks from parents included:

- **"**The program has become a great motivational source for him and has challenged and inspired him to set higher goals for himself and understand the value of higher education**"**
- "He enjoyed himself tremendously and had a rare opportunity to be exposed to the engineering profession."
- **"**As a parent I was amazed at how much he benefited from the program. My son told me the program helped him to "come out of his shell". He learned teamwork and leadership skills. He said he learned how business and engineering can be used to solve problems. He showed some self confidence and assertiveness after the program and I am really proud of him. Thank you for providing this program for the youngsters so they learn that even they can come up with solutions to our everyday problems in the community.**"**

Overall the program has promising results in exposing and motivating high school students to engineering, but it is apparent that they need to be exposed at an early stage. Considering the exit survey results on rising 10^{th} graders who attended the business of engineering program, 67% thought they had already decided on their career choice, and 92% overall felt they had somewhat decided on their career choice. Although this is the case, most of them were open to changing their minds and were willing to consider engineering as their career choice. More importantly, students wanted additional exposure with some wishing they could attend the program the second time and others opting for a longer program.

FUTURE WORK

The feedback from students and parents helped in assessing the successful implementation of the business of engineering approach. The workshops, field trips, design contests, and the design case study enabled in meeting the program goals, however, feedback information from parent and participants showed that there is room for improvement. Some students sited that CAD tools and demonstration was fun, therefore, the use of computer-aided design tools will be expanded as well as consideration of expanding the program to be longer than a week. Almost all workshops will also be converted to hands-on activity based workshops that will involve engineering demonstrations. Moreover, the focus will be on younger students instead of rising seniors in high school. Finally, the tracking of the participants' activities after the program will be enhanced to specifically find out whether the participants pursue and graduate with STEM degrees.

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