

AC 2007-1226: IMMERSING HIGH SCHOOL STUDENTS IN ENGINEERING AND ENTREPRENEURSHIP

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Immersing High School Students in Engineering and Entrepreneurship

Abstract

The University of Kentucky Engineering Summer Program is an immersive, one-week, residential program incorporating engineering and entrepreneurship curricula for Kentucky's top, rising high school seniors. The program's main objectives include: apprising students of the role of innovation in a global economy, educating them about the various engineering disciplines, informing students of the opportunities available to engineering graduates, acquainting them with the business development process, convincing students of the importance of being entrepreneurial, improving their communication and teamwork skills, and recruiting students for further engineering and entrepreneurial pursuits. The goals of the program are accomplished through the use of team building exercises, hands-on engineering labs, company tours, networking opportunities, and a group business venture competition. The program increases the participants' understanding of engineering and entrepreneurship. Additionally, it improves the students' attitudes toward engineering by combating stereotypes and demonstrating its expansive relevance. Demographic data on the program participants, their current academic pursuits, and program assessment results are presented.

Introduction

The primary objective of the Engineering Summer Program (ESP) is to apprise rising (to be) high school seniors of the importance of being innovative in a global economy through an immersive, one-week, residential program incorporating engineering and entrepreneurship curricula. Secondary objectives of the program include: educating students about engineering as an academic major, informing students of the numerous career and professional opportunities afforded to engineering graduates, acquainting students with the process of evolving innovative ideas into business ventures, convincing students of the importance of being entrepreneurial in their future endeavors, improving students' communication and teamwork skills, and recruiting students for further academic and entrepreneurial pursuits in the University of Kentucky (UK) College of Engineering. In order to meet these objectives, the students participate in a number of activities including team building exercises, hands-on engineering labs, engineering company tours, networking opportunities, a group business venture competition, and recreational activities. Through the group project, students are involved in concept development, product design, prototyping, business plan development, and public presentation.

This paper will be comprised of five main sections. The first section will outline the engineering and business curricular components designed to meet the stated program objectives. Next, a brief description of the capstone group design project and presentation competition will be presented. Subsequently, the college and community resources involved in the program execution will be discussed. An analysis of the Engineering Summer Program's successes and shortcomings using qualitative and quantitative assessment data compiled from participants' pre and post surveys will follow. Lastly, a summary of the lessons learned throughout the four years of the program's execution will be presented.

Curriculum

The students that participate in the Engineering Summer Program are thrust into a week-long itinerary that consumes their time from 7 am until 10 pm each day with activities that are designed to achieve the objectives previously mentioned in the introduction. A more detailed description of the core program objectives is provided in Table 1. A general description of the daily activities is provided below. Following each description, the outcomes from Table 1 that relate to the activity are listed.

Team building exercises – The Engineering Summer Program participants represent the top, rising high school seniors from around the state. They have diverse geographic, educational, ethnic, and family backgrounds. The students are arranged into teams that embody the diversity of the group, for the purpose of a week-long project. To foster teamwork, the groups participate in a number of activities that acquaint them with their teammates, orient them to the university campus, reward them for collaboration, and introduce healthy competition. A common theme among the activities is the use of contrived obstacles and artificial resource limitations to challenge the students to work together towards a common goal. Examples of successful activities include ice breakers, scavenger hunts, creatively themed skits, brain teasers, and activities (for people of varying physical abilities) in which one would likely participate on a “low ropes course” or a corporate retreat. (F)

Company tours – For many high school students, the only career professionals that they have the occasion to know and observe in the work place are educators and medical personnel. It is critical for the prospective engineers in this program to interact with engineers in their place of work. Care is taken to choose companies and sites that can provide the students with an opportunity to meet with engineers from various disciplines and to see them in assorted work environments. Alltech, Lexmark International, and Thiel Audio have provided tours for past programs. Additionally, this opportunity can be used to demonstrate to students the role of innovation in engineering and business as well as the opportunities that exist to be entrepreneurial in an established company. (A, B, C, D)

Hands-on engineering labs – The students are presented with an overview of engineering in general and the disciplines commonly offered by universities across the country. The program participants are then required to choose a subset of the fields that they would like to further investigate. Students are asked to select experiences from the following areas of study: Biosystems and Agricultural Engineering, Chemical and Materials Engineering, Civil Engineering, Computer Science, Electrical and Computer Engineering, and Mechanical Engineering. The students have the opportunity to learn about these fields with faculty and students from each discipline. The hands-on activities usually begin with a discussion of the area of interest, a presentation on career opportunities afforded by a degree in the specialty, followed by brief instruction on the principles in the field that will be demonstrated in later activities. Following the brief introduction and instruction, the students complete a number of hands-on demonstrations, laboratory experiments, or competitions. (B, C, G)

Networking opportunities – Throughout the week, students are given numerous opportunities to network with university faculty, staff, and students as well as prominent community leaders, established business owners, budding entrepreneurs, and career engineers. They are introduced to the importance of networking and the value of forming professional relationships. The students are prepared in advance for many of the networking events and are greatly encouraged to make sincere use of the opportunity. However, a few of the opportunities are “pseudo-spontaneous” and the students may find themselves chatting with an entrepreneur at the ballpark or ice cream parlor during a recreational evening activity. (A, B, C, D, E, F, G)

Group business venture competition – The cornerstone of the summer program is a group project that spans the entire program incorporating engineering, innovation, business, and entrepreneurial components. Through the group project students are involved in business concept development, product design engineering, rapid-prototyping, business plan formation, elevator pitches, and a group presentation. As such a significant piece of the program curriculum, the next section describes the project in greater detail. (A, B, C, D, E, F, G)

Table 1 – Program Objectives

A – Participants will develop an understanding of the importance of being innovative in an ever-expanding, global economy.
B – Participants will gain knowledge of engineering as a program of study, its various disciplines, and the academic rigor required of engineering students.
C – Participants will come to realize the numerous career and professional opportunities afforded to engineering graduates.
D – Participants will experience the many facets of evolving innovative ideas into business ventures.
E – Participants will become convinced of the importance of being entrepreneurial in their future endeavors.
F – Improvement of the participants’ communication and teamwork skills.
G – Increased likelihood of the program participants pursuing an academic degree from the University of Kentucky, UK’s College of Engineering, or an entrepreneurial career.

Capstone Project

A group design project and presentation encompasses all of the program objectives, requiring students to be innovative and to call on their knowledge and experience, both prior to and during the program, to propose a business venture. The students conceive a novel product, design and build a prototype, and give a presentation and demonstration on the last day. The presentation highlights their product prototype, explains its market potential and related business strategy, enumerates the features and associated benefits that the product affords for its consumers, and conveys what the team has learned to the other program participants. Additionally, students are required to identify the engineering skills they will need to bring their design to the marketplace. The presentation is given before the other program participants, the program staff, and a panel of community business leaders and entrepreneurs. Following the presentations, the students field questions from the panel. Lastly, the teams are called upon to present a 60-90 second elevator pitch for their concept before their parents.

To complete the project, each team is responsible for all of the following deliverables:

- New product concept
- Detailed project schedule / Gantt chart
- Product marketing plan
- Funding plan / financial analysis
- Intellectual Property search
- Design documentation / engineering notebook
- Interim progress reports
- Semi-functional prototype
- Brief business plan
- Elevator pitch
- Final presentation

Furthermore, in developing their business plan for the project, the students are required to address important issues such as conducting competitive analyses, developing a marketing strategy and brand recognition, proposing a funding plan, and speculating a growth plan. The deliverables are evaluated by the judges and awards are given to the groups based on their performance. The quality of the deliverables, especially the presentation and prototype, serves as an additional opportunity for the program coordinators to assess the success of the program.

Through the project and the completion of its diverse deliverables, the students are involved in and gain an appreciation for the important processes required of a successful, vibrant company (e.g. engineering, manufacturing and quality improvement/control, customer support, sales, marketing, finance, research, new product development, and legal). It is the expectation of the authors that the students' project experiences and their exposure to the business aspects of engineering lead them to an appreciation for the importance of innovation and its role in a knowledge-based, global economy.

Resources

Although the Engineering Summer Program could not occur without the resources and support of its sponsors, this section is not intended to describe the fiscal details of the program operation. More simply, this section will highlight the various resources utilized in executing the program.

Engineering and business students who have completed their junior year of studies or higher are typically employed as student mentors, serving as consultants to help guide the students through their design projects. They help the teams stay on task, locate resources around the engineering complex, and oftentimes find themselves honing their skills and broadening their experiences along with the program participants. In the evenings, student counselors in-residence are used to attend to the participants and address any issues the evening may bring. Behind the scenes, the program directors are coordinating the logistics of the entire event and developing on-the-fly backup activities. When they are not mastering just-in-time techniques, the program directors act as quality control engineers, ensuring that the goals of the curriculum are met, chaperoning the group at all activities, and serving as mentors and counselors in-residence for the program.

In addition to the inspiring support from all of the program staff, faculty and student volunteers are depended upon for hands-on engineering education. In order to give the students the best exposure to engineering and its many areas, students investigate the disciplines with faculty members in that field. They tour research laboratories and complete undergraduate-level experiments with the faculty members and their student assistants. As a result, the college and its facilities are considered as a perpetual “open house” to the students of the program. Some students have even used the college’s rapid prototyping facilities and manufacturing center for components of their project prototypes. However, ESP also has dedicated classroom facilities, lab equipment, and a myriad of odds and ends for the students to complete their design projects.

In conjunction with the university office of residence life, the college of Engineering sponsors a living-learning community, arranging for an entrepreneurial engineer to live in the residence hall, mentoring the students throughout the academic school year. The ESP students also reside in this residence hall during the program and the entrepreneurial engineer-in-residence serves as a program mentor. The facilities and environment provided by this hall complement the summer program and its objectives.

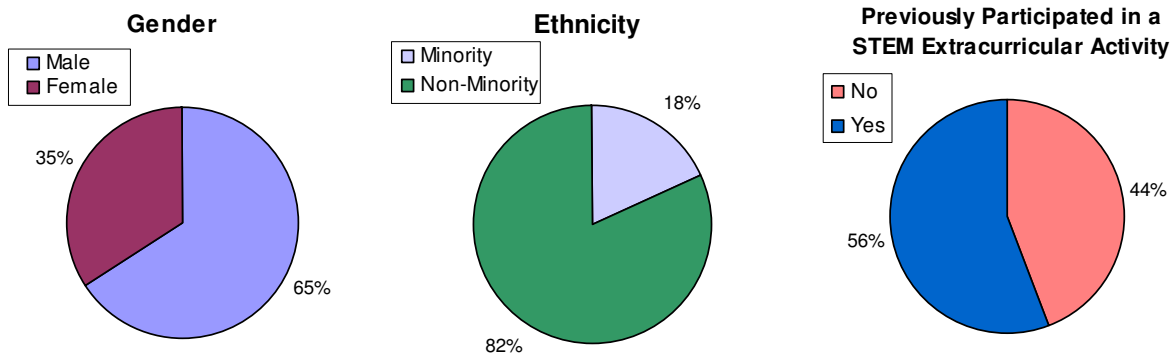
Assessment

The top, rising, high school seniors from across Kentucky are invited to apply to the program based on their performance on any one of three national tests, the PSAT, ACT, or SAT. The program participants are then selected from the pool of applicants based on the quality of their submitted application and résumé. While the program is competitive, one of the greatest competitions is in convincing the students to choose this program instead of or in addition to the other programs targeting the same pool of potential applicants. Thankfully, the program sessions have been well attended with 136 students completing the program during the six one-week sessions offered in the summers of 2004 through 2006.

The engineering summer program actually began in the summer of 2003. During its first year, the components of the program, its curricula, and its demographics were varied among three sessions to determine an effective model for future programs. As a result, the focus was on self-improvement and student evaluations were relied upon to tailor the program for future classes. Following the 2003 program, the curriculum was revamped, objectives were redefined, and student assessment tools were developed. Since the initial improvements, the program and assessment methods have remained relatively unchanged. In discussing the successes and shortcomings of the program, demographic data about the program participants and assessment results for the participants subsequent to the 2003 session will be presented.

Figure 1 shows demographic data about the composition of the Engineering Summer Program participants. The data was collected on the students from six co-ed sessions conducted over three years. In addition to the data presented in Figure 1, the students have an average ACT Composite (or equivalent) score of 30.

Figure 1 – ESP Demographic Data



Beginning with the ESP class of 2004, all participants completed a pre-survey designed to assess their knowledge and comfort with engineering and entrepreneurship as a part of the registration process. At the conclusion of the program, the students were asked to complete a post-survey with questions identical to the pre-survey. The surveys from each respondent are linked and the change in the responses is evaluated. Approximately 95% of the participants completed both assessment surveys. Table 2 shows the survey topics, their association to the program objectives of Table 1, the percentage of student responses that exhibited non-negative change, and the percentage of student responses that exhibited a positive change.

Table 2 – Assessment Survey Results

Survey Topic	Objectives	Non-Negative	Positive
Knowledge of engineering	A, B	97.7%	85.0%
Knowledge of entrepreneurship	A, D	95.3%	74.4%
Likelihood of becoming an engineering major	C, G	68.2%	27.9%
Likelihood of starting a company in the future	E, G	69.8%	30.2%
Likelihood of attending a college or university in Kentucky		64.3%	21.7%
Likelihood of attending the University of Kentucky	G	69.0%	23.3%
Engineering is not just a salaried desk job	A, B, C	81.9%	51.2%
Engineering relates to / applies to science and mathematics	A, B, C	85.3%	31.0%
Engineering applies to non-science disciplines	A, B, C	89.1%	54.3%
Engineering provides a good foundation for a career in Kentucky	A, C	82.2%	41.1%
Engineering provides a good foundation for careers outside the state	A, C	84.5%	31.0%

In addition to the pre and post survey method of assessment, the program coordinators' observations of the students during the team building activities and the group project serve as an evaluation method for objective F from Table 1. Also, the review of the capstone group project by the program coordinators and the project judging panel serve as a method of assessing the

success of the program in regards to all of the objectives in Table 1. The enrollment of ESP participants in the University of Kentucky and its College of Engineering serves as a method of evaluating the program's achievement of objective G.

As is demonstrated by the results in Table 2, the Engineering Summer Program and its curriculum is most successful at helping the students with their understanding of engineering and entrepreneurship. Secondly, in exposing the students to the many facets of engineering, the ESP participants have an improved understanding of engineering as it applies to not only the science, technology, engineering and mathematics (STEM) areas, but to non-science areas and professions. Furthermore, prevalent stereotypes in the press¹ about engineers confined to a desk or cubicle are combated. Historically, the state of Kentucky has been wrought with low self-esteem and a general belief in the unavailability of engineering and "new economy" jobs. In fact, the state of Kentucky ranks 42nd among the states in terms of knowledge economy jobs and 47th in terms of a science and engineering workforce². While the authors are proud of the fact that a large majority of the program participants have a better understanding of the career opportunities afforded by an engineering degree, they are more duly pleased by the fact that the participants realize career opportunities are afforded to someone of an engineering background in Kentucky.

Unfortunately, while the participants overwhelmingly leave with an improved view of engineering and entrepreneurship (approximately 85% and 74% respectively), one area with much room for improvement is increasing the likelihood of the participants to pursue engineering and entrepreneurial endeavors, especially since the students who decide to apply to the ESP most likely have a greater interest in engineering than the general student population. Additionally, the fact that the Engineering Summer Program participants represent the top, rising high school seniors from all geographic areas of the state, and approximately 44% of the students had no previous participation in STEM related extracurricular events or competitions is both validating and concerning.

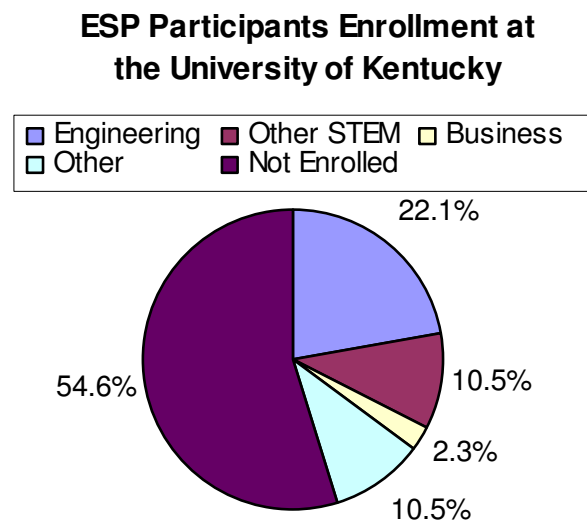
In regards to the non-survey assessment methods, it is important to attest that all groups participating in the program produced every deliverable required of the capstone design project. Generally speaking, the presentations and product concepts have been well received by the presentation judges. One reviewer from a local science and technology NPO stated that the student presentations were of the same or higher caliber than many of the business proposals pitched to her organization. Each year, the program coordinators are surprised by many of the product concepts, and they are confident that the students' self-assessed sense of augmented knowledge is largely do to the capstone project, and their feeling of success in completing it.

Figure 2 shows additional demographic data regarding the enrollment of ESP participants in various programs at the host university. As the most recent graduates are not eligible for college enrollment as of yet, this data is compiled on the students from the four sessions conducted in 2004 and 2005. While nobody can claim that one particular event or activity is the reason for one's enrollment in a particular university or program of study, the authors are proud to have over 45% of the ESP participants in attendance at the University of Kentucky with nearly 72% of those students in attendance pursuing studies in a STEM discipline. No data is available regarding the number of program participants that are pursuing academic degrees at universities other than the program's host university. This enrollment data serves as a preliminary measure of

the program’s success at achieving objective G. To further assess the success of the program at reaching this goal, the program coordinators will continue to monitor the enrollment and progress of its participants through their academic careers at the University of Kentucky. Currently, the program has not been in existence long enough for its first participants to complete four academic years in their undergraduate careers.

To gain a better understanding of the significance of this data, it is important to discuss the potential applicant pool for the ESP. The University of Kentucky’s admissions office provides the program coordinators with an “honors list” of rising juniors from Kentucky based on their national test performance. All of these students are invited to apply for the program; many do not. In examining the enrollment demographics of the students from this list that did not participate in the ESP, less than 17% of the students are attending the University of Kentucky, with approximately 51% of those in attendance pursuing degrees in STEM areas.

Figure 2 – Engineering Summer Program Participant Enrollment Data



Lessons Learned

It is the opinion of the authors that a summary of what the Engineering Summer Program can accomplish and has accomplished may be best represented by responses from its participants. Although the program coordinators typically receive unsolicited, praising thank you letters from the participants or their parents following each session, the pre and post responses of the students to open-ended survey questions will serve to describe the program’s successes. Five paired quotations from program participants are listed below. Statements marked with a “Bx:” are responses to the question: “What do you hope to gain from your experience at ESP?”—solicited before the student participated in the program. Statements marked with an “Ax:” are responses to the question: “What did you learn from your experience at ESP?”—solicited after the student participated in the program.

B1: “I have always wanted to do something with math and physics. The problem is, I don’t know exactly what engineers do or how much math and physics are involved. By attending ESP I hope to improve my knowledge of the engineering profession and find out if it’s right for me.”

A1: “I learned exactly what engineers are and what they do. This helped me to realize engineering is for me.”

B2: “I hope to further my understanding of engineering and entrepreneurship in general and to learn what I need to get closer to choosing a college major and career plans.”

A2: “I learned a lot about entrepreneurship and I decided it would be a great idea to try some day. Before, I knew about civil engineering, but now my view of engineering has broadened immensely. I had a great time and look forward to seeing you at the University of Kentucky.”

B3: “A greater understanding of engineering as a major and as a potential career. I hope to gain some knowledge and abilities that I can’t get from my high school that may help me in pursuit of an engineering career.”

A3: “I got a better understanding of entrepreneurship though experience. I learned about what an engineering degree would entail and where I might be able to go from there. And I learned that it interests me.”

B4: “I hope to gain more knowledge of college life as well as insight into the engineering profession and degree. I predict that ESP will be very informative and will help solidify my choice to pursue engineering.”

A4: “I learned about the differences between the engineering disciplines, which were not really clear to me before. I also got a taste of the hard work involved in entrepreneurship, and how much actually goes into a finished product.”

B5: “I hope to gain exposure to engineering fields and careers within those fields. I hope to learn more about engineering in general in order to better shape my future goals and college / career choices.”

A5: “I was certain chemical engineering was among my top choices. I now realize that I’m leaning towards mechanical / aerospace engineering. I realize that I can engineer and design, which is something I have been uncertain of in the past.”

Following the initial sessions of the Engineering Summer Program in 2003, a number of lessons were learned about the effectiveness of the target group demographics and the program curricula. First, in an attempt to reduce the potential problems that may arise from co-ed sessions with students of this age group, the program initially had a reduced number of co-ed events as well as some all-male events to accommodate the pool of applicants. It is the opinion of the authors that unless one is conducting a human psychological study on the learning and behavioral habits of all male groups, the co-ed sessions are far more preferable. It was observed that the students were more productive and cooperative (and of better hygiene) in co-ed situations.

Initially, the program curriculum required the students to participate in hands-on engineering laboratories in each of the main disciplines offered by the University of Kentucky (civil, chemical, electrical, and mechanical engineering). While this format increased each student's exposure to the various areas of engineering, many of the students grew exhausted near the end of the week. It was also observed that occasionally some students had a cultured disinterest in one of the particular disciplines. As a result, the authors have found that presenting a general survey of the many areas of engineering and allowing the students to select three areas of study from a larger group of fields was generally better received by the students. In addition to this change, the fourth hands-on session was replaced with an engineering company tour to mix up the routine and allow the students the opportunity to interact with engineers in the workplace.

It was also learned by the program coordinators that when executing a program with an ambitious, demanding schedule, it is easy for all involved to become exhausted. Each year in the program evaluations, an overwhelming student consensus of the need for more free time exists. However, this lack of free time and level of exhaustion is intentional—less idle time given to the students results in less opportunity for trouble to arise. As a result of the schedule intensity, it is critical for the program staff and volunteers to have recuperation time between multiple sessions. It is the experience of the authors that the students' reception of the program schedule and satisfaction with its execution is heavily coupled to the disposition and demeanor of the program mentors and staff throughout the week.

The reader may be familiar with pre-engineering summer camps offered as outreach programs through other universities. Many of them have been presented at ASEE conferences in the past³⁻⁵, and some of them even share the same name and acronym as the program described in this paper. While the previously mentioned summer programs³⁻⁵ have different durations, focuses, target audiences, and associated costs of attendance, they have a few common elements. The programs³⁻⁵ feature engineering department tours and associated lab activities as well as hands-on design activities that focus on completing predefined tasks and problems. The outreach camps³⁻⁴ rely on formal instruction in fundamental areas such as calculus, chemistry, physics, etc. and they design the hands-on projects to relate to and connect the course material. Additionally, the outreach activities³⁻⁴ target high performing high school students in engineering related courses, through the recommendations of high school math and science teachers.

Unlike the previously mentioned programs, UK's Engineering Summer Program focuses on innovation and idea generation through the design / business concept project. In researching and developing their business ventures, the students investigate the related engineering and science principles, defining the instruction content as well as incorporating self-discovery. The UK ESP

recruits students based on their high aptitude for achievement in many areas as evinced by their national test performance. However, many of the students apply to the program as a result of their interest in STEM areas. New to the realm of outreach summer camps, the ESP coordinators are encouraged to find that the current number of participants enrolling at the University of Kentucky is roughly 50% higher than that experienced by another program³. Despite some common curricular elements among ESP and other programs, the authors hope that the engineering education and engineering entrepreneurship communities-at-large have gained helpful insight and ideas from the results presented herein.

As the world becomes flatter⁶, the authors believe that the earlier one is exposed to engineering and entrepreneurship—more specifically the creativity, innovative thinking, and problem solving skills developed when pursuing both areas—the more likely one is of having a long-term successful career. It is alarming to discover that for roughly 44% of the rising high school senior participants, the Engineering Summer Program is their first involvement in a STEM related outside-of-school activity. Hirsch⁷ cites various studies that detail the negative stereotypes students commonly have of engineering and the correlation between a student's attitudes towards engineering prior to starting college and his or her success and persistence in the program of study. This combined with the steady increase in the US science and engineering workforce over the past twenty years and the projected increased future demand for engineers do to retiring employees and current degree production levels⁸ poses a problem for a US “knowledge-based” economy. One way of addressing this problem is by increasing the enrollment and retention of engineering students seeking degrees in this country. Hopefully, this program and many other programs like it will continue to enlighten students to the possibilities provided by an engineering degree, improving their attitudes towards engineering and their aptitude for generating jobs in a knowledge-based economy through engineering entrepreneurship.

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