Lessons Learned From a Summer Engineering Outreach Program

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Abstract

The University of Kentucky Engineering Summer Program (ESP) is an immersive, one-week, residential program incorporating engineering and entrepreneurship curricula for Kentucky’s top, rising (to be) high school seniors. The main objectives of the program include: apprising its students of the role of innovation in a global economy, educating them about engineering as an academic major, 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, and is a useful tool for student recruitment. Additionally, it improves the students’ attitudes toward engineering by combating stereotypes and demonstrating its expansive relevance in an attempt to increase the participants’ likelihood of studying engineering. Demographic data on the program participants, their current academic pursuits, and program assessment results are presented. Details on the program’s evolution over its four year execution are provided.

Introduction

The Engineering Summer Program is a one-week, residential, outreach program that seeks to educate Kentucky’s top, rising high school seniors about the academic, professional, innovative, and entrepreneurial aspects of engineering. The program also acquaints the students with life on a college campus, and attempts to improve their communication and teamwork skills. To accomplish these goals, the program curriculum incorporates team building exercises, hands-on engineering labs, company tours, networking opportunities, a group design project competition, and recreational activities. Through the group project, students are involved in concept development, engineering design, prototyping, business plan development, and presentation.

This paper will be comprised of three sections. The first section will provide a detailed outline of the program’s curricular components and how they relate to its stated objectives. Next, an anecdotal discussion of the evolution of the program curriculum over its four year existence will be presented. Lastly, quantitative assessment data examining the participants’ awareness of the
opportunities afforded by an engineering education as determined through pre and post surveys as well as a discussion of the program’s successes and shortcomings 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 program 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)

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**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. A significant amount of time is devoted to idea generation and concept evaluation. Following the brainstorming activities, the students conceive a novel product, design and build its prototype, and give a presentation and demonstration on the last day. The presentation highlights the prototype’s functionality, explains its market potential and related business strategy, enumerates the features and benefits that the product affords 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 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

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. 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. (A, B, C, D, E, F, G)
Table 1 – Program Objectives

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

Following the initial sessions of the 2003 Engineering Summer Program, an analysis of the feedback from the participants and their parents led to a number of changes to the program logistics and 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 four 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.

When arranging the hands-on engineering labs, it is critical that the faculty and graduate student presenters are well informed about the background of the students as well as the objectives of the hands-on session and the program as a whole. Although the student participants have a common grade level and have demonstrated high academic achievement, they have widely different academic backgrounds. The authors have observed students who have completed Calculus II in the same class / session as participants whose highest level of mathematics education is in Algebra I or Geometry. Ideally, the hands-on sessions work best when the program coordinators complete a dry run of the exercise and work with the faculty members to tailor the activity based...
on previous student feedback and their knowledge of the group. Likewise, it is the experience of
the authors that discussing the background of the students and the goals of the program with the
engineers and presenters prior to the company tour results in a more positive experience for the
students. The program coordinators have worked with numerous companies that have provided
tours for the group, adapting the visits to the students and program objectives, and the companies
have always been enthusiastic participants and extremely accommodating.

It is the hope of the authors that the students take knowledge, experience, and many abstract
things away from the program. However, many students expressed their desire to take home
some of their work-product to show their parents and friends. Unfortunately, the group design
project that results in one prototype is not a feasible item for the students to take with them. As a
result, the program coordinators worked with some of the faculty members to modify the hands-
on labs to include activities that result in portable projects. Hopefully, the program participants
will be good stewards and use the projects to introduce others to engineering. In addition, a brief
3D design project for all students was added to the curriculum. The students receive basic
instruction in the Rhino 3D® design tool and construct a personalized 3D model. The models are
then sent to the university’s rapid-prototyping facility and the students now receive a 3D SLA
model to take home as well.

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.

While one would hope that the admissions process would be successful at selecting hardworking
students and that the schedule would reduce the opportunity for problems to occur, it
occasionally happens that one or two less than cooperative students arrive for the program.
Initially the camp coordinators would expend a lot of staff resources to keep these students
involved and they operated under a multiple “strikes” discipline policy to address issues that
arose. However, after a few years of program execution the policy has evolved to one far less
tolerant that allows for a more immediate dismissal. Although dismissing someone from the
program is always difficult and likely to have negative affects on recruiting the student to study
engineering at the university, it is sometimes best for the group as a whole. Surprisingly, the
authors have witnessed gratitude from the remaining students after a few disciplinary dismissals.

Assessment and Summary

The top, rising, high school seniors from across Kentucky are invited to apply to the Engineering
Summer 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.

As was previously mentioned, the engineering summer program began in the summer of 2003 as a pilot program with the initial focus on self-evaluation and program improvement for future sessions. 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 of the six sessions subsequent to the 2003 program 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 a non-negative change, and the percentage of student responses that exhibited a positive change.
Table 2 – Assessment Survey Results

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

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 press 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 workforce. 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 a 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. 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 due 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 University of Kentucky. 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 high school 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.
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. When asked, “What do you hope to gain from your experience at ESP,” one of the participants responded, “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.” After completing the program, the same student was asked, “What did you learn from your experience at ESP?” The student replied, “I learned exactly what engineers are and what they do. This helped me to realize engineering is for me.”

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 past\(^3\)-\(^5\), and some of them even share the same name and acronym as the program described in this paper. While the previously mentioned summer programs\(^3\)-\(^5\) have different durations, focuses, target audiences, and associated costs of attendance, they have a few common elements. The programs\(^3\)-\(^5\) 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 camps\(^3\)-\(^4\) 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 activities\(^3\)-\(^4\) 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. As a result, it is common for the ESP mentors to be called upon to provide impromptu instruction on math, science, or engineering topics to the students. 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 program. 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 flatter, 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. Hirsch 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 levels 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.

Bibliography