AC 2010-2303: ADVENTURES FOR FUTURE ENGINEERS: K-12 OUTREACH STRATEGIES

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Adventures for Future Engineers: K-12 Outreach Strategies

Abstract

Within this manuscript, we will present three K-12 residential summer engineering outreach approaches. Each of these programs has been designed and executed with the aim of instilling an interest in engineering among middle and high school students, with an emphasis of reaching underrepresented populations. The three programs introduced in this paper are the ExxonMobil Bernard Harris Summer Science Camp (EMBHSSC) for rising sixth, seventh, and eighth graders, Introduction to Engineering (ITE) for rising high school juniors and seniors, and the Leadership, Education, and Development Summer Engineering Institute (LEAD-SEI) which is also geared towards rising high school juniors and seniors.

Each of these curriculums consists of hands on activities, lectures and presentations given by University professors and graduate students, team building exercises, field excursions and tours of both faculty laboratories and the campus. In addition to these traditional enrichment activities, the LEAD-SEI program initiated a group research project strategy, which was highly praised by visiting sponsors, participants and faculty members.

One unique aspect of the EMBHSSC program is the spring follow-up activity that is provided for all campers and their parents. At this follow-up event, all campers and parents participate in the hands-on activities and parents are given the opportunity to learn about other additional enrichment programs in which their children can apply.

Within this paper we will describe the basics of each residential summer program, the recruitment and marketing strategies, the participant selection process, and approaches used to engage these middle and high school students in additional enrichment programs. Beyond this, we will discuss the activity design criteria of each program as they serve a variety of age groups and diverse backgrounds. The paper will conclude with an overview of findings from these three programs, including the quantitative distribution analysis of the applicants' race and gender, curriculum critiques, ongoing assessment survey reviews, characteristics of the most successful activities, and lessons learned. All of these programs departmental implementation and evaluation experiences will be presented in a format that can be adapted at other higher educational institutions.

Introduction

Several reports have indicated that the Unites States is challenged with retaining and graduating enough well-qualified science, technology, engineering, and mathematics (STEM) workers to meet the needs of the economy. [1-5] This shortage of technically skilled workers, threatens the United States stature as a global leader in scientific and technological innovation. At the same time, the demography of the United States continues to shift and it is reported that by 2035 that the present minority population will become the majority.[4,5] Unfortunately, the National Science Boards 2008 indicators show that underrepresented groups collectively (African Americans, Hispanic Americans, and American Indians/Alaska Natives) constitute 24% of the total U.S. population, 13% of college graduates and only 10% of the college educated population in science

and engineering occupations.[3,6] Therefore, it is imperative that we attract and encourage an interest in STEM among all students, especially those from underrepresented populations that have been underutilized within these fields in the past.

To accomplish this goal, our office has hosted and created a variety of programs to attract, encourage and sustain K-12 students from underrepresented populations in the pursuit occupations in the science and engineering workforce. The foundational core of each of these programs stems from suggestions that the U.S. education system is falling short in its ability to interest girls and minorities in STEM. Nine-in-ten of the Fortune 1000 STEM executives surveyed say that science should be the "fourth R" in elementary school classrooms. They also advocate that the best way to teach science is using a hands-on, inquiry-based approach and the earlier students are exposed to hands-on inquiry, the better.[4,7] A 2007 report by the Bayer Corporation indicates that 51% of students 5 to 10 years old show an interest in science.[4] At the combined age levels of 11 to 17, another 33% of students begin to show an interest in science and beyond these age brackets the percentage drastically decreases. Thus, to assure a diversified STEM workforce for the future, we must have students participate in hands-on based enrichment program and activities at an early age.

The Basics of Each Program

ExxonMobil Bernard Harris Summer Science Camp - The ExxonMobil Bernard Harris Summer Science Camp is a cost-free real world, self-confidence building camp that instills an interest in STEM among middle school students. Throughout this camp, students begin to grow and learn how to become active participants in a technology enriched society, while gaining life-long skills. This program also aims to motivate students to stay in school while nurturing leadership, citizenship, and the values of responsibility, fairness, and respect.

As our office has hosted the ExxonMobil Bernard Harris Summer Science Camp for three consecutive years, ample excitement has been generated for the program throughout the state by word of mouth from previous participants and our website. Thus, we recruit program participants from around the state, with an emphasis on recruiting students from the local and surrounding area school districts. When this program initially began in 2007, it was rather difficult to recruit willing minority participants to attend this camp. Thus, formal letters and brochures with camp details were distributed to middle school principals, counselors, and STEM teachers. Since this time, our office has found that with minimal advertisement and marketing, the number of candidates has doubled each year and we are overwhelmed with enthusiastic and well qualified applicants. This suggests that there is a great need for camps of this stature and the selection process becomes more complicated each year as enrollment must be maintained between 48 and 52 campers due to budget constraints. In fact, the list of waitlisted applicants continues to grow each year.

Successful applicants for this program are rising 6^{th}, 7^{th}, or 8^{th} graders with a minimum overall GPA of 3.0 (B), a minimum math/science GPA of 3.0, and scores on standardized math and science tests that are at least equal to the tests' median scores. Preference is given to students from traditionally underrepresented populations in STEM fields that meet these eligibility requirements. In addition to the minimum requirements, successful applicants must also exhibit

an interest in math and science according to a statement of interest and recommendations from present math and science teachers.

Selected participants reside on campus for two weeks and participate in interactive, team-oriented, collaborative learning activities and classes with professors and graduate students from the engineering and science departments here on campus. The core curriculum of the ExxonMobil Bernard Harris Summer Science Camp is designed around the national standards for math, science, technology, and the development of 21st century skills, as the targeted participants are in the middle school age bracket. Being one of thirty camp sites across the country, we are required to design our activities, experiences, field excursions, and events around The Harris Foundation Project-Based Inquiry Learning model,[8] a theme and core problem. The Project-Based Inquiry Learning model permits students to actively participate in solving a problem by learning and acquiring knowledge. Thus, campers are engaged daily in inquiry driven environments where they work as teams on assignments to design products, complete assignments, and report plausible solutions to the original core problem. Beyond these practical skills campers are given the chance to interact with a number of STEM professionals, learn more in depth about STEM careers, and tour the university under guided supervision. All of their experiences and thoughts are recorded in their notebooks nightly during journal time. This activity not only gives campers time to relax, but it provides them with the opportunity to reflect back on what they have learned. Given this break, we anticipate that many campers retain the information learned daily, which improves their cohorts follow-up activity.

The spring follow-up activity is another unique aspect of the EMBHSSC program. This event is provided for all campers and their parents. At this follow-up event, all campers and parents participate in hands-on activities and parents are given the opportunity to learn about other additional enrichment programs in which their children can apply. Future activities and programs that are mentioned for this age group include: GEAR-UP, RAPME, First Robotics, Systems Robotics Day Camp, other programs offered by the engineering student organizations, LEAD-SEI, and ITE.

Introduction to Engineering – Introduction to Engineering (ITE) aims to introduce rising high school juniors and seniors to the theory and practice of engineering and engineering disciplines through lectures, labs, demonstrations, exercises in engineering design, applied math, and basic science over a one-week period. This $400 program delves outside of the scholastic engineering realm, and affords participants an opportunity to attend seminars on college admissions and financial aid, and receive a guided tour of the University. Furthermore, participants receive an introduction to life as an undergraduate engineering student as they experience many aspects of University life in a supervised atmosphere, including living in residence halls, eating in dining halls around the grounds and interacting with fellow students from all over the country.

As this program is in its 11th year, interest has been generated throughout the state and beyond. Therefore, we recruit program participants from around the country, but an emphasis is placed on recruiting students within our state. To ensure we have a large number of applicants from our home state, we send out brochures and program applications statewide to all high school Principals, counselors, and STEM teachers. As these brochures and applications are sent to more

than 1,200 people, we must conduct several rounds of application review as many applicants far exceed the minimum requirements.

Applicants for the Introduction to Engineering program are selected based on scholastic performance (minimum 3.0 GPA), performance in college-preparatory courses in math and science, standardized PSAT, SAT and ACT test scores, previous enrollment in pre-engineering classes and a desired interest in and motivation for attending ITE as expressed in the applicant's personal essay. Based on the applicant criteria and pool, we find that most chosen participants excel in mathematics and are well equipped with the basic knowledge of biology, chemistry, and physics. Thus the activities for this group are designed to challenge their current knowledge while allowing them to grow their analytical and problem solving skills and explore engineering career options.

Daily ITE participants take part in a calculus workshop which tests their mathematical skills. In addition to this daily workshop, these students also attend and participate in a chemistry laboratory where they expand upon lectures that they have heard throughout the week and conduct experiments on polymers and different materials. Within small groups, these students spend a significant amount of time creating and designing a solar car for a final team competition to be held at the end of the week. Unlike the EMBHSSC, no follow up activity is held for these students although their names and information are given to the admissions office so that they may send these rising seniors applications for admissions and additional information about the university. As many of the ITE participants are going into their last year of high school, there are no additional summer enrichment programs that we may offer them through our office, but all are encouraged to get involved in activities offered by the student organizations advised by our office, the University and research at the undergraduate level.

Leadership, Education, and Development-Summer Engineering Institute - The objective of this three week multi-year residential program is to lay a foundation that will expose tenth and eleventh grade students from African American, Hispanic, Native American, under-represented Asian and economically disadvantaged communities to careers in engineering and other technical fields by challenging them to solve real-world challenges through various learned approaches. The overarching goal of this collaborative partnership between LEAD, Google, a number of higher educational institutions and industries is to create a diversified engineering workforce for the future.

To recruit these future engineers, LEAD is relying on the success of the LEAD business model and more than 25 years of experience LEAD to identify academically strong high school youths with proven mathematical ability that have interests in more technical fields of study to participate in the newly created Summer Engineering Institutes.[9] In addition to experience and success, aggressive outreach, marketing, and recruitment strategies are also employed. As LEAD advertises and recruits students for the Summer Engineering Institutes, they solicit the help of undergraduate engineering school admissions officials, high school counselors, and human resource staff members to recommend potential candidates for admission into the SEI programs. These prospective candidates must rank in the top 10% of their class, score in the top 25% on USA National Board Exams, and come from all over the United States and Puerto Rico.

Each applicant must prepare an application which includes biographical information, two essays, leadership experience and personal recommendations. Candidates for this program are in their sophomore or junior year of high school with a 3.2 average or better and combined test scores of at least 100 on the PSAT, 1000 on the SAT (critical reading and math combined), or 22 on the ACT. Potential candidates must be US Citizens or permanent residents and are required to have successfully completed a minimum of two sciences and Algebra II.

LEAD staff, Google administrators and Executive Directors from each LEAD-SEI site convene to review the applications, and select exceptional to students participate in the summer LEAD-SEI cohort. At the time of acceptance, participants are required to pay tuition for the three-week program, possible additional program fees - depending on the SEI - and travel fees. To off-set the cost and fees, partial or full tuition and travel assistance is available to those who are deemed eligible based on submitted financial disclosure information.

Upon arriving to campus, the selected participants are involved in team building exercises followed by collaborative hands-on laboratory research experiences in one of many engineering disciplines. SEI participants also engage in computer science programming classes, engaging discussions about entrepreneurship and engineering disciplines with graduate students, faculty, and invited speakers. Field excursions and tours of the historical campus were also incorporated into the schedule to allow participants to become acclimated to the campus. Additional highlights of LEAD-SEI are the interactive chemistry laboratories, evening fireside chats with industry executives, late night laboratory collaborations, and guided site visits to corporations such as Google and NASA Langley, the Entertainment Technology Center, Robert L. Preger Intelligent Workplace, Carnegie Science Museum, and Smithsonian Institution. Beyond these activities, participants also gather information about University admissions, financial aid, scholarships, the engineering curriculum and most importantly the pursuit of engineering as a profession. At the conclusion of the three weeks, teams presented their final research projects during a morning session followed by an afternoon session in which they demonstrate their newly developed programming expertise.

The LEAD-SEI experience does not conclude with the final presentations as rising juniors have the opportunity to participate for a second summer prior to their senior year of high school. This multi-year program gives students the opportunity to experience engineering departments at two of the nation's top undergraduate engineering institutions while evaluating all the different career options and pathways of engineers.

Overall, each of these summer programs has a unique feature that makes it stand out, but they all provide the service of increasing the number of students interested in the pursuit of engineering and technology degrees (**Table 1**). This increased interest in STEM, will equip Fortune 1000 STEM executives with a diversified workforce capable of escalating the United State's innovation and global standing.[7]

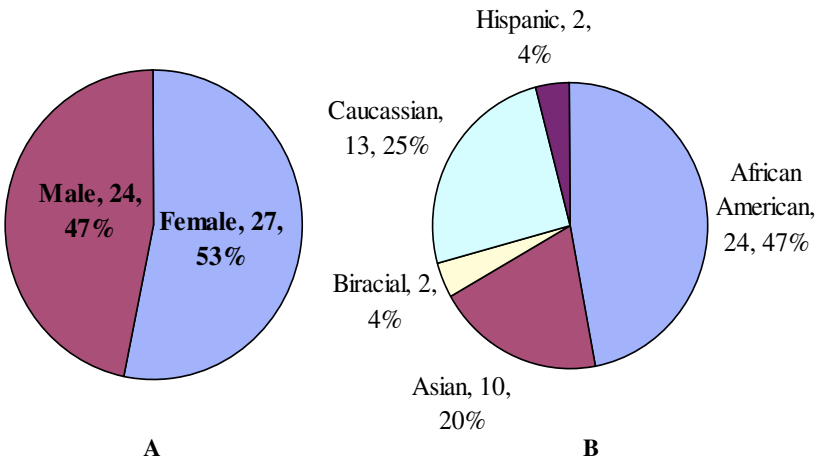
	EMBHSSC	ITE	LEAD-SEI
Residential Time Frame (Weeks)	2	1	3
Number of Participants in 2009 Program	51	46	30
Multi-year			√
Follow-up Activity	√		
Hands-on Activities	√	√	√
Additional Enrichment	√	√	√
2009 Program Fee	No Fee	$400	$35 Application $1,200 Program Fee
Program Fee Assistance	N/A	√	√

Table 1: Program Comparisons

Outcomes

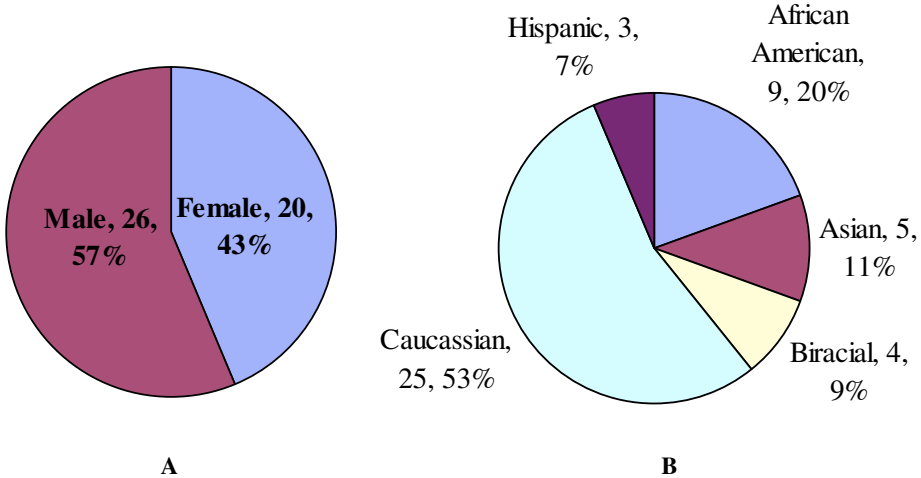
Quantitative distribution analysis of the applicants' race and gender – With all of our programs we try to ensure an equal distribution of genders and races. In fact, the Harris Foundation dictates that the resulting body of participants in the EMBHSSC must be half male-half female and be diverse with respect to race/ethnicity. As shown in **Figure 1A**, we complied with the rules set forth by the Harris Foundation as the resulting body of our 2009 campers was 47% male and 53% female. With respect to race/ethnicity, our camper population was very diverse as shown in **Figure 1B**.

In addition to the equality amongst gender and race, EMBHSSC also aims to support the educational development of economically and/or socially disadvantaged students. Thus, in our recruitment efforts, we try to recruit from districts where a large percentage of students are on free and reduced lunch. In Virginia alone, 34% of students have been approved for free and reduced lunch.[10] As students were selected from 16 different school districts during the summer of 2009, the average free and reduced lunch percentage for the participating school districts was determined to be 36%.[10] In evaluating the student profiles, a majority of the applicants did not qualify for free and reduced lunch. Of the selected participants, approximately 10% of all the participants were on free lunch. The gender and race breakdown of this 10% populace is 20% female, 80% male, and 100% African American.



Figures 1A and B: 2009 EMBHSSC Participant Demographics

In evaluating the 2009 Introduction to Engineering program demographic data, we found that the gender breakdown was 57% male and 43% female (**Figure 2A**). Analyzing these percentages against the admitted incoming first-year gender ratios at our university, we find that we are on par as the Class of 2013 was comprised of 60% males and 40% females. With respect to race/ethnicity **Figure 2B**, shows a slightly different picture than that which was seen for the EMBHSSC. Combined and as defined by the NSF, the percentage of underrepresented groups that participated in the 2009 ITE program was 35%. Comparing this value with that of EMBHSSC (**Figure 1B**), we found that 13% more students from underrepresented populations participated in EMBHSSC than in ITE. Delving deeper into this divergence, we analyzed the applicant profile data for ITE and found that Caucasians were nearly three times more likely to apply than African Americans and eleven times more likely to apply than Hispanic Americans for this program. An inspection of the EMBHSSC applicant profile paints a significantly different picture as Caucasians and African Americans applied at approximately the same rate. In evaluating the number of Hispanics that applied to EMBHSSC, we find that Caucasians and African Americans apply at a higher percentage than Hispanics.



Figures 2A and B: 2009 ITE Participant Demographics

To better understand the observed differences in race/ethnicity of the enrichment programs, we compared the applicant pools of the EMBHSSC and ITE programs with the state and national ethnicity data (**Figure 3**).[11] In total, we received more than 250 EMBHSSC applications, of which only 191 were complete. From **Figure 3**, we see that in comparing state and national ethnicity data, EMBHSSC very successfully attracted African Americans (28%). However, the ITE program, which requires a $400 program fee to off-set the cost of on-campus housing and board, only attracted 19% of African American candidates. This value is on par with the national data and only slightly higher than the state average. In reviewing the applicant data for these programs, we also noticed that percentage of Asian applicants for both EMBHSSC and ITE were at least two times higher than the state and national ethnicity data. Comparatively, both EMBHSSC and ITE have lower Hispanic applicant percentages than the state and national data. The observed changes in applicant and participant demographics of underrepresented groups can likely be attributed to the cost of the ITE program. According to the U.S. Census, the 2008 median household income was $34,218, $37,913, $55,530, and $65,637 for African American, Hispanic, Caucasian, and Asian families respectively.[12] Unfortunately, as depicted in the applicant and participant demographics, we find that this program fee deters a large number of exceptional students from underrepresented groups from applying and accepting our invitation to participate in this program. To try and increase these numbers we have made a limited number of scholarships accessible to outstanding students, but with the present economic downturn there is not enough funding available to equate the ratios with respect to race and ethnicity across the board. These comparative analyses have provided us with a useful direction in future recruiting strategies.

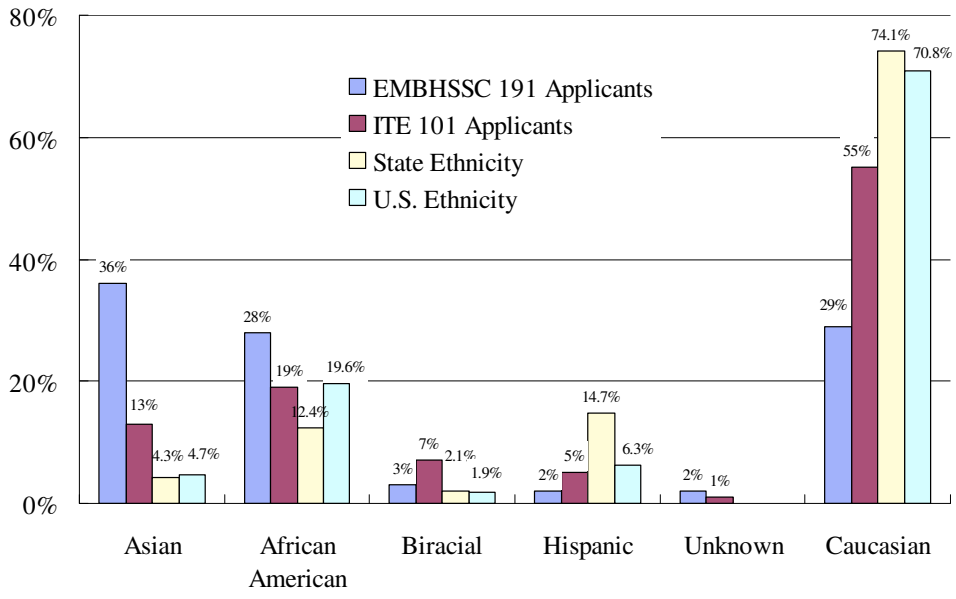
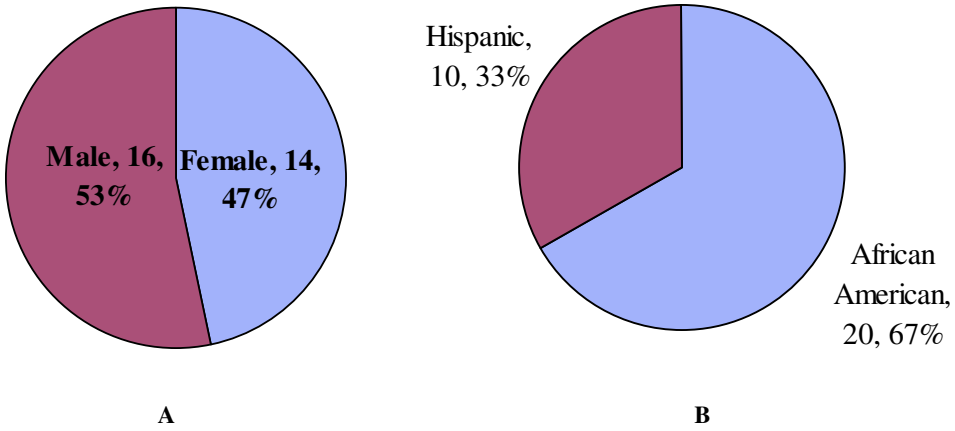


Figure 3: 2009 EMBHSSC & ITE Applicant Race/Ethnicity Data

Based on the data seen above, one would anticipate that the demographics for the LEAD-SEI would show similar results as a program and travel fee is required by the participants. With

respect to gender this is the case as the 2009 LEAD-SEI cohort at our university was 53% male and 47% female (**Figure 4A**). The race/ethnicity of the participants at our university is extremely different from that of the 2009 ITE program (**Figure 4B**). The demographics of this 2009 LEAD-SEI cohort indicate that a vast number of underrepresented minorities are interested in pursuing engineering as a career, but to participate in summer enrichment programs such as these that require a program fee, partial or full tuition and travel assistance must be made available as previously suggested.



Figures 4A and B: 2009 LEAD-SEI Participant Demographics

Curriculum Critiques - At the completion of each program, an evaluation is conducted to gain quantitative and qualitative assessments of each programs curriculum. All in all, program participants value the experiences received from these enrichment programs. In categorizing and ranking the activities, we find that the hands-on assignments, projects, and demonstrations receive rave reviews when compared to a typical lecture or presentation. The 2009 ITE evaluation (**Figure 5**) results rank the hands-on solar car construction (5.9/7.0) and chemistry laboratory (5.6/7.0) as the top two STEM activities. Collectively we found that the basic presentations and lectures scored 4.7 out of a possible 7.0. Similar comments were observed in the LEAD-SEI evaluations. This three week program incorporated the unique feature of team laboratory collaborations under the guidance of faculty members and graduate students. For many students, this was their first time conducting research. Although this was the case, approximately 80% of the participants ranked this activity with a 4.5 on a 5.0 scale. Comparatively, we found that on average about 60% of students enjoyed the faculty presentations and panel discussions. This 20% drop in enthusiasm probably stems from the lack of critical thinking required to listen. Evaluations from the 2009 EMBHSSC, show corresponding results to the programs mentioned above. Many campers found the presentations uninteresting if no demo or hands-on component was included. When asked for their comments about the hands-on activities a distinct change in the tone of voice can be felt from simply reading their statements. In fact, at 30 different EMBHSSC sites, over 1,500 campers wrote more than 95% positive comments about hands-on activities and questioned why these activities were not offered at school. These critiques and assessments suggest that students want to know more about engineering and technology, but it must be presented in a way that gets them involved.

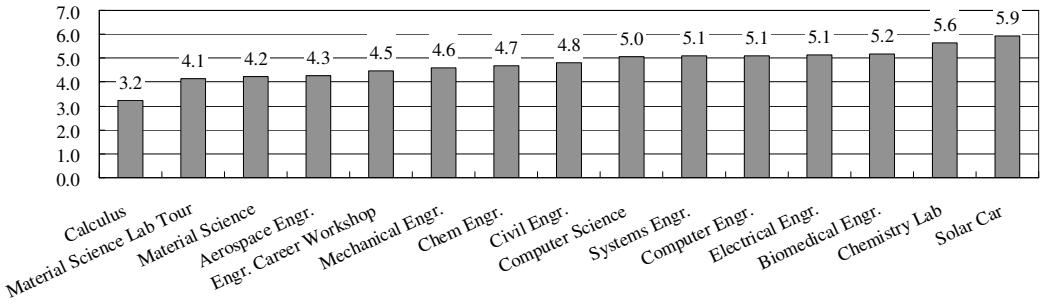


Figure 5: ITE 2009 Evaluation

Assessment of Program Impact – As presented, our office offers a number of summer enrichment programs geared towards creating a diversified workforce for the future. The overarching question that we and persons involved with these types of programs should answer is what impact are these programs having on past participants choices about future endeavors. Our office has gathered survey information from participants in the three 2009 summer enrichment programs about how our programs have increased their knowledge about engineering and influenced their decisions to pursue engineering in the future.

Prior to attending these programs, students acknowledge that their knowledge of engineering on a scale of 7.0 was about 3.6. After participating in these programs, their knowledge increased to nearly 6.0 out of a 7.0 scale. Thus, our programs enable students to learn what it is to be an engineer. Beyond learning what engineers do, the results from our survey indicate that we have generated an interest amongst participants to pursue engineering in the future. A side-by-side comparison of the data (**Figure 6**) shows that there is an increase in the number of students that foresee themselves pursuing engineering for each program.

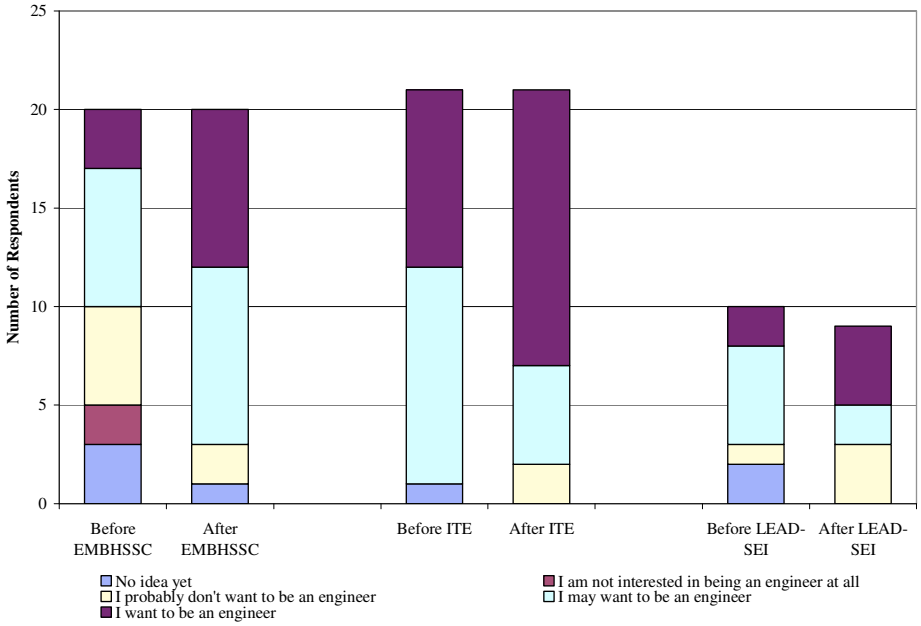


Figure 6: Participants interest in pursuing engineering

To ensure that the above data are of significant value, we used a paired sample t-test to examine the statistical differences observed in how much students knew about being an engineer before and after our outreach programs.

Shown below is an example of the paired t-test for the EMBHSSC survey. We evaluated the question "how much do you know about being an engineer" and conducted the paired t-test on the 20 responses received. The calculated t-Stat 8.72 exceeds the two-tail t-Critical 2.86 in order for the difference between the means to be significant at the 1% level. This value indicated that the means for the students' engineering knowledge level are significantly different at *p=4.57E-08.*

	EMBHSSC Engineering Knowledge Before	**EMBHSSC Engineering Knowledge After**
Mean	3.55	5.55
Variance	1.10	0.68
Observations	20	20
Pearson Correlation	0.42	
Hypothesized Mean Difference	0	
df	19	
t Stat	-8.72	
P(T<=t) one-tail	2.29E-08	
t Critical one-tail	2.54	
P(T<=t) two-tail	4.57E-08	
t Critical two-tail	2.86	

In evaluating this same question for all three programs and conducting the paired sample t-test we found that all p-values were less than 0.01 (**Table 2**). Therefore the statistical studies show that with 99% confidence, the survey data supports our conclusions that "the outreach programs increase participant knowledge about engineering".

	EMBHSSC	**ITE**	**LEAD-SEI**
How much do you know about being an engineer	4.57E-08	1.17E-07	4.12E-04

Table 2: Program paired sample t-test data

Additionally, from our survey we were able to gather data from the LEAD-SEI and ITE high school students about their intended major during their undergraduate studies and the likelihood that they would apply for admissions at our university. Of the 30 respondents to the ITE and LEAD-SEI surveys, there was at least a two-fold increase in the number of participants that plan to apply to an engineering school after having completed the summer program (**Figure 7A**). As for applying to our university, increases were also observed (**Figure 7B**).

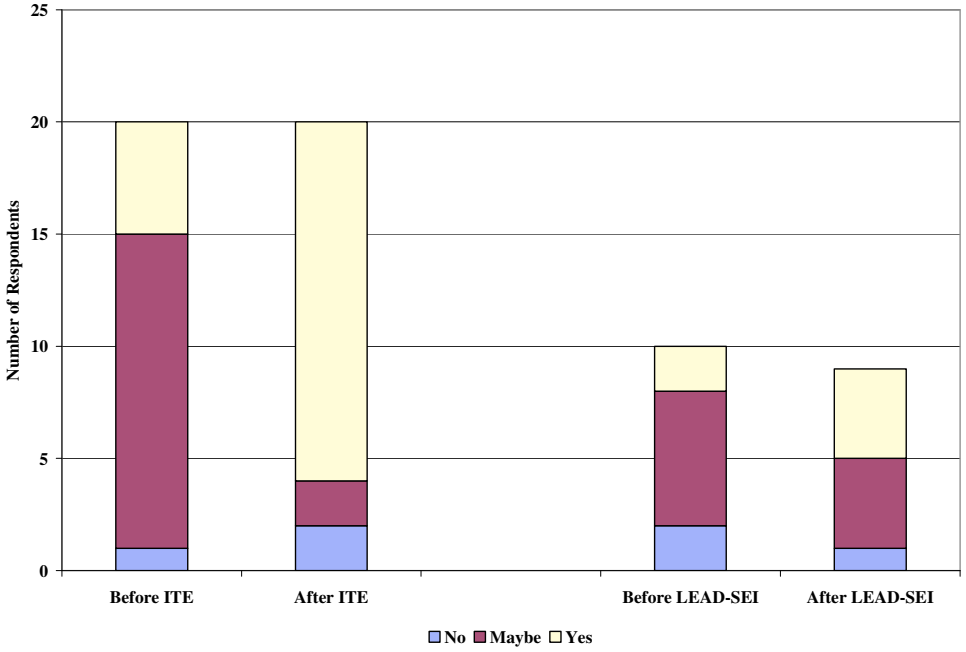


Figure 7A: ITE and LEAD-SEI Participants Applying to an Engineering School

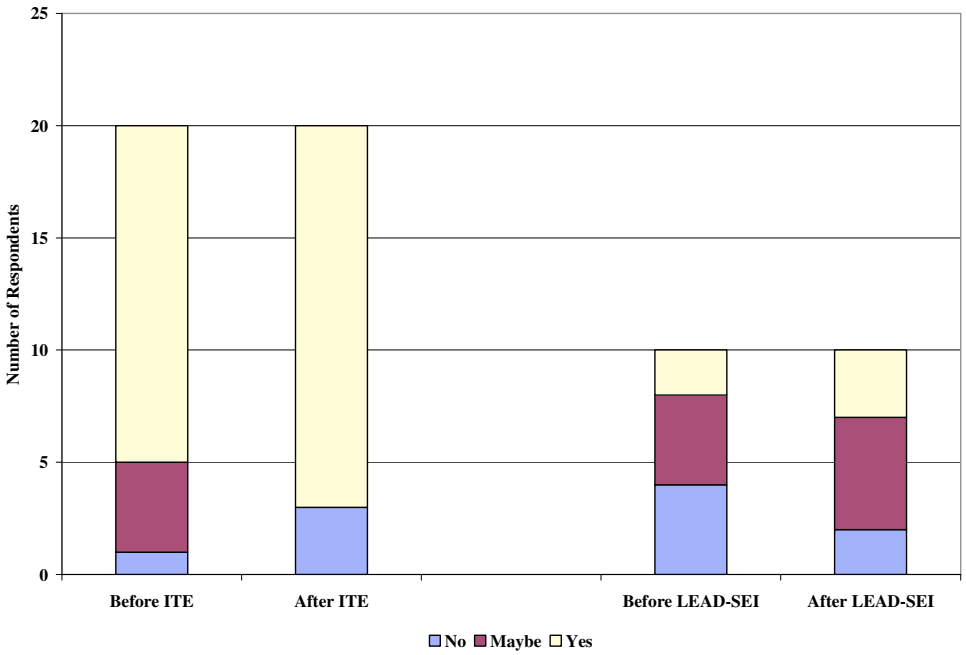


Figure 7B: ITE and LEAD-SEI Participants Applying to our University

Overall these programs have significantly affected participants in a positive manner. Respondents to the surveys from all three programs have indicated that their program was an eye-opening experience to the world of engineering. They enjoyed the hands-on activities, the team-work, research, college life, and most importantly the introduction to engineering. These evaluations have enabled us to begin to assess the soundness of our programs and ensure that we are helping to create a workforce that will surpass and sustain our global competitors.

Lessons Learned and Conclusions

Our office provides enrichment programs for a number of age groups and we have learned specific lessons which are detailed further within this section. To begin with, we have found that recruiting students from the local and surrounding area school districts is advantageous as it easy to have students be involved with follow-up activities and events hosted by our institution. The difficulty in this recruitment strategy is that many of these students know each other from their present schools which in turn limits the interactions they desire to have with other students. Based on this observation, we would suggest that a maximum of two to three participants be recruited from the same school. By incorporating such a strategy, we anticipate that participants will be required to become better acquainted and develop friendships that will surpass the program.

In evaluating our participant demographics and the demographics at the state and national level, we feel as though we need to reach out to students that meet the requirements, but may not have knowledge of our programs. To reach out to these students, we will contact our State Department of Education and inquire if they can put us in touch with individuals that can provide us with insights into the school districts who have limited science, technology, engineering and mathematics courses. In addition to this, programs such as ITE and others run across the country require an application or program fee. Based on the above data (**Figure 3**), we know that this can be a major deterrent for underrepresented populations. Thus, our office continually tries to create collaborative partnerships with corporations, foundations, and industries to acquire external funding for scholarships to offset the cost of such fees.

As a whole, these summer enrichment programs work due to the hands-on activities and opportunities designed for each age group that the majority of them do not experience in their classrooms. In fact one participant of the LEAD-SEI program stated that “this opportunity allowed him to decide that he wants to be a biomedical engineer”. Another participant stated that “My experience this year really convinced me that I can actually do engineering and I most definitely plan to study it in college, specifically chemical engineering, which I had not even considered before”. These statements alone suggest that these summer enrichment programs are helping to create a diversified STEM workforce for the future.

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