AC 2011-2864: ENHANCING THE FUTURE OF AMERICA’S COMPETITIVENESS THROUGH ENTREPRENEURIAL ENGINEERING

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Carolyn Vallas is a General Faculty member and the Director of the Center for Diversity in Engineering (CDE), at the University of Virginia’s School of Engineering and Applied Science (SEAS) since 1998. Her responsibility over the past twenty five years has focused on diversity initiatives with emphasis on outreach and retention programs for women and minorities in engineering. This involves a strong collaborative working relationship with engineering faculty and other departments on campus as well as with school districts, governmental and private industry. In addition, she is the PI and CoPI for several National Science Foundation (NSF) grants; such as a Research Experience for Teachers Site (REU); NSF STEP grant, collaborating with Thomas Nelson Community College, which concentrates on increasing the number of transfers who graduate from SEAS and entering the engineering workforce and the NSF VA_NC_LSAMP grant. She is also the Executive Director of three stellar STEM outreach precollege programs: Introduction to Engineering, ExxonMobil Bernard Harris Summer Science Camp and the LEAD: Summer Engineering Institute (SEI). She has particular research interest in the education of the underrepresented population in the STEM fields; focusing on teachers and students preparation, retention and persistence factors.

She is also the past National President of her professional organization the National Association of Multicultural Engineering Program (NAMEPA); where her interest continues to be to develop partnerships to broaden NAMEPA’s footprint nationally. She works very closely as the Faculty Advisor with the student chapters of the National Society of Black Engineers (NSBE), the Society of Hispanic and Professional Engineers (SHPE), the American Indian Science, Engineering Society (AISES) and the Society of Women Engineers (SWE). She is a member of the Women in Engineering Programs and Advocates Network (WEPAN), American Society for Engineering Education (ASEE) and Chair’s SHPE national committee for Advisors of chapters across the country.

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Wraegen Williams graduated from Virginia Commonwealth University in December 2007 with a PhD in organic chemistry. After completing her doctoral studies, she obtained a lectureship position at a small university where the minority population of both students and faculty was limited. This issue piqued her interest in discovering more about diversity issues in higher education. As a Mirzayan Fellow at the National Academies, she gained insight as to how polices are prepared, reviewed, and implemented to create a diversified workforce. She feels that the Fellowship aided her pursuit of a career in higher-educational administration. Currently, Wraegen works as a research associate in the Center for Diversity in Engineering at the University of Virginia. As a research associate, she helps to organize and execute a number of summer programs that are designed to interest middle and high school students in science and technology disciplines. Additionally, she takes time to mentor and provide support to undergraduate students who will soon become the future workforce of research scientists and engineers and interacts with faculty members, department chairs and deans that are interested in volunteering their time to the numerous science, technology, engineering and mathematics (STEM) programs that the Center coordinates.

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Enhancing the Future of America’s Competitiveness through Entrepreneurial Engineering

Abstract

The Center for Diversity in Engineering at the University of Virginia (U.Va.) hosts the Leadership, Education, and Development Summer Engineering Institute (LEAD-SEI). LEAD-SEI is a unique engineering outreach approach that provides rising tenth and eleventh grade students from underrepresented backgrounds with a glimpse of the practical innovation and entrepreneurial spirit that will be needed for America to compete in the diverse global economy. This outreach effort has been designed and implemented with the aim of instilling an interest in computer science, engineering and entrepreneurship among the future innovators of America.

LEAD-SEI’s three-week core curriculum consists of a team-based research project and computer science. These components allow groups to develop innovative solutions, products/prototypes, business plans and technology driven presentations to address real world problems; including the global challenges of the 21st century. In addition to the aforementioned, participants learn the scope of the different engineering fields from University professors and graduate students. Beyond discovering computer science and engineering, team building exercises, site visits of corporate and government facilities, and other traditional enrichment activities are incorporated into the curriculum.

The innovative entrepreneurial technology team-based approach of LEAD-SEI has aided in the recruitment of underrepresented students to the fields of computer science and engineering. Qualitative curriculum assessments of the computer science component vary while the team-based research has piqued all participants’ interest in engineering based disciplines. Quantitative post-program surveys indicate that the LEAD-SEI has changed 90% of participants’ perceptions of pursing an engineering or computer science field. This data is confirmed by the fact that 43% of the graduates that participated in LEAD-SEI at U.Va. are majoring in computer science or engineering at their post-secondary institution. Thus, the U.Va. LEAD-SEI program is helping to create future computer scientist and engineers from diverse backgrounds; thereby enhancing the future of America’s competitiveness.

Introduction

Once upon a time, the United States was the world’s dominant science and technology based innovator, yielding high wage jobs, elevated standards of living, economic and political leadership that far surpassed any other country in the nation. Now as we enter the second decade of the 21st century, the United State’s global share of activity in research, science, technology and engineering focused industries has declined, jeopardizing our status as the world leader in innovation. Therefore, we must rectify the situation to guarantee our prominence in the rapidly changing global economy.
Many have stated that the United States is in turmoil due to its ill investment in education and innovation.\textsuperscript{3-6} For example, America once led the world in high school graduation rates, but currently we rank 18th out of 24 industrialized countries.\textsuperscript{1, 7} Nationwide, less than 10\% of students in the United States pursue science, technology, engineering, and mathematics (STEM) disciplines, whereas 75\% of students in India and China are pursuing educational opportunities in these arenas.\textsuperscript{8, 9} This is concerning as scientific advances, innovation, and technological change are drivers of economic performance and essential to success in advanced economies, like the United States.\textsuperscript{10} A decreased interest in STEM, coupled with an innovation deficit places the United States in a prominent position to become a third world country. Thus, America must tap into its rich resources - both natural and human - to overcome the decline in innovation.\textsuperscript{4}

To help combat the current innovation deficit within the United States, the Center for Diversity in Engineering (CDE) at the University of Virginia (U.Va.) has hosted the Leadership, Education, and Development-Summer Engineering Institute (LEAD-SEI) for the past two summers. This three week multi-year residential program aims to expose tenth and eleventh grade students from African American, Hispanic, Native American, underrepresented Asian and economically disadvantaged communities to careers in engineering, computer science, and other technical fields by challenging them to creatively solve real-world challenges. The overarching goal of this collaborative partnership between LEAD, Google, a number of higher educational institutions and industries is to instill future engineers with the practical ingenuity, innovation, leadership and entrepreneurial spirit needed for America’s competitiveness in the diverse global economy.

LEAD relies on more than 25 years of experience and success with the LEAD business model to recruit future computer scientists and engineers into their entrepreneurial spirited engineering program. To identify potential candidates for the Summer Engineering Institute, LEAD seeks out academically strong high school youth with proven mathematical ability and interests in technical fields of study. Prospective recruits are US Citizens or permanent residents in their sophomore or junior year of high school with a minimum 3.2 grade point average that have successfully completed a minimum of two sciences and Algebra II, and obtained combined test scores of at least 100 on the PSAT, 1000 on the SAT (critical reading and math combined), or 22 on the ACT.\textsuperscript{11}

Each potential SEI participant prepares an application that includes their biographical information, two essays, leadership experience, and personal recommendations. All completed applications are reviewed by LEAD staff, Google administrators and Executive Directors from each LEAD-SEI site. Through this application review process U.Va. has had the opportunity to interact with approximately 60 students of varying genders and races as depicted in Figure 1. All LEAD-SEI cohorts at our university were approximately equal with respect to gender (Figure 1A). From Figure 1B one can see that the racial/ethnical make-up of the 2009 cohort was 2:1 African Americans to Hispanic/Latinos. During the summer of 2010, this ratio changed significantly as African Americans and Hispanic/Latinos participants were accepted at approximately the same rate to our SEI. Both of these underrepresented
groups were in drastically larger percentages than the one student of Native American heritage. In all, the demographics of the LEAD-SEI cohorts indicate that a vast number of students from underrepresented populations, both male and female, are interested in furthering their knowledge about the fields of engineering and gaining practical experience to determine if this is the right career pathway.

![LEAD-SEI Participant Gender Demographics](image1.png)

**Figure 1A: LEAD-SEI Participant Gender Demographics**

![LEAD-SEI Participant Race/Ethnicity Demographics](image2.png)

**Figure 1B: LEAD-SEI Participant Race/Ethnicity Demographics**

**Curriculum Overview**

Summer Engineering Institute participants are involved in a variety of activities that include: team building exercises, engaging discussions about entrepreneurship and engineering disciplines with graduate students, faculty, and invited speakers, an interactive chemistry laboratory, campus tours, evening fireside chats with industry executives, nightly research collaborations, guided site visits to corporations such as Google and NASA, computer science lectures and laboratories, and a hands-on collaborative research experience. Although all these elements work in tandem to make the LEAD-SEI experience phenomenal, the last two activities are critical elements that have helped to make LEAD-SEI a success at U.Va. Hence, we will give an in depth overview of these components and show how they work.
together to afford participants the opportunity to gather information about the pursuit of engineering and computer science as a career while obtaining the underpinnings as a future entrepreneur.¹¹

For the past two summers LEAD-SEI participants have worked with the Scratch programming language to create and share interactive stories, animations, and games. Using this program, they discover important mathematical and computational ideas, while also learning to think creatively and reason systematically. Prior to the initial summer of the program, some suggested that Scratch would be too basic of a program for the SEI participants, while others worried that a more challenging programming language would turn novice programmers away from computer science. Without knowledge of the students programming background, Scratch was implemented. During the initial classes and over the two summers it was found that selected participants had varying programming knowledge and abilities. Thus more advanced students were encouraged to program in languages such as C++ and Java, allowing them to enhance their programming skill set. In reviewing curriculum critiques, more advanced students felt that this was a good way to keep them actively involved with the computer science course. One student even commented that, “the Scratch program was a really good way to start programming if you have no experience, but I took AP Java during my junior year. For this reason the professor gave me some pretty difficult programming competition problems to work on. This kept me entertained and I really had a great time in class.” Another student stated that they “enjoyed the simplicity of Scratch after having had negative programming experiences previously.” These comments justify both the concerns and use of Scratch throughout the LEAD-SEI program. Other qualitative critiques from participants to be discussed vary widely based upon the student’s familiarity with programming and their own capability.

The hands-on laboratory research experience, which is the second critical element of our program, evens the playing field amongst all participants as all of them are novice in a university research setting. Each summer the research experience available to teams varies as the CDE is dependent on faculty, postdoctoral researchers, graduate students, and their lab space. Over the past two years, research teams have worked in the engineering disciplines of biomedical engineering, chemical engineering, civil and environmental engineering, mechanical engineering, and electrical and computer engineering. Research teams are assigned after participants have been provided with an overview of each field of engineering either by faculty members or graduate and undergraduate students. Based on their desired interests, SEI participants select and rank the top two/three areas of engineering where they would like to conduct research. Using these selections, the executive program director and lead counselor(s) assign teams on the first full day of the program (Figure 2). On the second day and there after, teams work together for approximately three hours a day to propose and research an innovative solution to address one of the complex problems of the 21st century. Past research projects have included designing and testing a product for a Florida based company that would help clean up the recent oil spill to conducting experiments to determine if ethanol from corn is a viable replacement for petroleum.
At the conclusion of the three week program teams are responsible for presenting their engineering design research as a business venture to an audience of their peers, families, program administrators, and invited corporate representatives that help to judge the presentations. Each final presentation must consist of PowerPoint that gives an overview of the proposed product. Within the presentation, teams are charged with developing and incorporating a commercial or animation that represents their new product/business venture using the programming language of Scratch, C++, or Java. The formulated animation or commercial depicts how the product works, the advantage to the product, and more importantly how the proposed product or idea would help society. By working together to create these formal presentations, several students mentioned that they learned to work with others as a team, throughout the highs and lows. Based on these comments, we believe that students have cultivated some of the attributes of the 2020 engineer and are well on their way to being “made” into the entrepreneurs of the future.¹², ¹³

**Qualitative Curriculum Critiques**

Since the initiation of LEAD-SEI at U.Va., we have spoken with and read student evaluations about the curriculum. From both conversations and evaluations we have come to find that participants value the program, but they would like to see other curricular changes. Most frequently, the students commented on the research and computer science aspects of the program. Overall, participants found the hands-on research facet of this program to be phenomenal. For many of them, the research was an eye opening experience that helped them to better understand the work of an engineer.

“Words cannot describe the wealth of knowledge I acquired from my research project.”
“Before LEAD-SEI, I thought engineering was just building things, but now I know more about the different types of engineering and what they do.”

“The research was extremely informative as I learned about things in depth that I would not have even learned in school. I also learned that research takes a lot of work, but it makes you more knowledgeable.”

Comments about the computer science course vary depending upon the student's knowledge and background of computer programming. Those students that have a background in programming would like to see a more advanced computer science component, but a general consensus from participants is that they want the incorporation of other engineering classes.

“This program was an amazing learning experience. I only wish that we could have had different engineering classes, instead of just computer science. The programming language used in computer science (Scratch) does not take into consideration that some students have programmed before. For next year maybe LEAD can offer advanced versions of computer science.”

“I really did enjoy learning computer science. I never thought I would like it, but after creating my own animation and games, I see computer science is not impossible or even boring and I am excited to show off my new computer science skills.”

“This class taught me that computers aren’t all that complicated and I can see myself working on them and/or video games someday.”

Although the curriculum of the LEAD-SEI is not completely perfect, the program structure and key components are making a strong impression and changing the perceptions about engineering for future generations.

Each summer at least 90% of participants have said that the LEAD-SEI program has changed their perception of studying computer science or an engineering field. Highlighted below are some of the most significant qualitative responses to the following question. Did LEAD-SEI change your perception of the field of engineering?

“This program opened my eyes to a lot of opportunities that I wouldn't have otherwise thought about. I liked that we had different engineers come and speak to us about their respective field. They helped me see that there is so much more that I can do with an engineering degree, than with most other things. I wanted to thank you again, for giving us this chance to work with great professors, students, and peers. This was a summer that I will never forget.”

“It definitely did. I’ve never considered majoring in engineering, but honestly I think it was because of my lack of knowledge on what engineering truly was. Now, as a rising junior, I am really considering majoring in chemical or mechanical engineering. This
experience opened my eyes to a new view on life.”

“After visiting the Entertainment Technology Center and having so much fun with my game in Computer Science, I’m now sure more than ever about programming video games.”

“Yes, I knew that I was interested in math and science, but I still wasn’t sure if I wanted to go into engineering because I wanted to do business, but now I know it is possible to do both.”

Quantitative data from post-program surveys also reveal that the numbers of participants that desire to pursue an engineering discipline has increased each summer following the program (Figure 3). Additionally, post-program survey reviews also indicate an increase in the number of participants that are interested in attending engineering schools after graduation (Figure 4). All of the gathered data suggest that LEAD-SEI is making a difference to aid in the recruitment of underrepresented students to the fields of computer science and engineering.

**Figure 3:** Future Plans of LEAD-SEI Participants

**Figure 4:** LEAD-SEI Participants Interest in Applying to Engineering Schools
Although these data and personal expressions show where LEAD-SEI participants interests lie, the real question is whether or not this programs impact holds true as participants venture into various undergraduate institutions across the United States.

**Future Pursuits of LEAD-SEI Participants**

Since the inception of this program at U.Va., 21 students have graduated from high school from the initial LEAD-SEI cohort and continued on to post-secondary institutions across the country. These graduates represent 43% females, 57% males, 62% African American, and 38% Hispanic Americans. Graduates from our program, have chosen to attend a number of the U.S. News and World Reports Best Colleges for 2011. In gathering data from LEAD headquarters and past participants, we found that 22% of females and 58% of males have chosen to major in engineering and/or computer science (Figure 5).

![Figure 5: LEAD-SEI Participants Post-Secondary Majors](image)

Based on this information, we know that the data from Figures 3 and 4 holds true as a number of graduates that participated in our LEAD-SEI program are majoring in computer science or engineering.

**Conclusions**

Through the LEAD-SEI program, the CDE at U.Va. provides the opportunity for high school students to enhance their engineering and entrepreneurial spirit; creating future leaders of the world. In large part, this program works due to the hands-on research and computer science components. A former LEAD-SEI participant, told the LEAD headquarters that the “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 LEAD-SEI. This year I was so grateful for the exposure to all different types...
of engineering. Our projects took a lot of hard work, but they were well worth it. I was sad to see the three weeks fly by so quickly! I can honestly say LEAD has changed my perspective and my life! Based on this statement, we know that LEAD-SEI is making a difference. Continuing to host programs such as LEAD-SEI that draw on diverse groups has benefits beyond meeting the needs for scientists and engineers as diversity is both a resource for and strength of our society and economy; especially when innovation is a critical goal.  

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