

Diversifying Engineering Education for Richmond Area Program for Minorities in Engineering*

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The Richmond Area Program for Minorities in Engineering Summer Engineering Institute (SEI) consists of comprehensive hands-on activities, and mentoring of women and minority students in the quest to increase the presence, retention and the advancement of girls and minorities in engineering and science. The SEI is a three five-week long endeavor, with multiple engineering-based team projects design to stimulate middle and high school students to consider engineering as a career. Each team is required to make two oral presentations throughout the program: one with their class and the other at the closing ceremony. Family members, school officials, and industrial representatives are invited to campus to celebrate the accomplishments of the SEI participants. As a result of the engineering-based projects, the SEI provides the students with realistic hands on experience that helps them with the transition from theory to real engineering practice. This paper attempts to diversify engineering education while providing a uniform program grounded in a fundamental set of engineering projects and principles.

Keywords: K-12 education; outreach; pre-engineering; summer camps; minority students; engineering; diversity

INTRODUCTION

AS TODAY'S GLOBAL COMPETITION in the science and engineering workforce increases, it is a moral and economic imperative that the U.S. sustains its preeminence. In 2005, women accounted for 19.5% of BS degrees awarded (of which 5.3% and 5.8% were awarded to African-Americans and Hispanics, respectively), down from 20.3% the year before. It is important to note that the U.S. workforce consists of roughly 46% women, and yet fewer than 22% of women hold jobs in Science, Technology, Engineering, and Math (STEM) disciplines [1]. These large disparities can be directly tied to the under-representation of women and minority students in these disciplines throughout college and university campuses. Unless, there is evidence of full and equitable participation of men and women in the STEM discipline, the nation may lose its competitiveness in STEM workers, such as has already been seen in many computer industries. Thus, increasing the presence of women and minorities in academia is a means to our nation's competitive edge in the STEM workforce by providing diverse viewpoints and approaches in the STEM industries.

With a stake in developing tomorrow's engineers, nine Richmond industries (ALCOA (Reynolds), Alstom Power, Brenco QBS, Dominion Virginia Power, Dupont, Dupont Teijin Films,

Honeywell, Philip Morris USA, and Verizon) have successfully encouraged this diversity by sponsoring the development of the *Richmond Area Program for Minority in Engineering*, a K-12 outreach program for middle and high school students. It has been noted that the overarching male-dominated group of scientists possess a uniform perspective on the world [2]. Therefore, it is necessary to increase diversity by building a critical mass of women and minorities in engineering and science disciplines in order to increase the perspectives of the scientific community, strengthen the rigor of the scientific method, and allow the programs to be self-sustaining.

The *Richmond Area Program for Minorities in Engineering* is a local non-profit organization. It was officially incorporated in July 1978 to establish a mechanism by which minority students can be encouraged to consider engineering and science as a profession, thereby assisting in the national effort to alleviate under-representation of minorities in the engineering professions. The SEI is an exemplary program of collaborative efforts that bring together three partner institutions: Virginia State University, Virginia Commonwealth University, and J. Sergeant Reynolds Community College, with the passion, experience, and knowledge to set strategic directions to establish, sustain, and improve the SEI feeder system across the engineering and science disciplines. The organization has the commitment and involvement of students, teachers, parents, school offi-

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cials, business, industry, and other interested community partners to develop the community's science and engineering talent demands.

The SEI is a three/five-week academic program divided into five phases. Each phase addresses the needs of a specific grade and academic level. Phases I through III are three-week sessions, whereas Phase IVA and IV is a five-week program. Phase IV students have the opportunity to earn college credits. The collegiality fostered by Phases I–IV is one of the most attractive aspects of the SEI and introduces its participants early to what it means to be part of a community of scholars. All of which enables the students to get a feel for the university campus and the engineering discipline. This paper identifies the elements in the SEI and the conduct of the program that ensures a great experience for the pre-college students, their teachers, and their industrial partners.

ENGINEERING-BASED PROJECTS

Although most middle and high school students take only the minimally required math and science classes in schools, girls generally obtain higher grades in math and science than boys, but often girls choose to abandon those subjects in high school because they do not see themselves pursuing a career in engineering or technology [3]. The impact of these facts nationally is that the number of students selecting engineering as a major is declining. Therefore, the main objective of the SEI is to diversify engineering education for minorities by providing the students with a comprehensive understanding of the principles of engineering and giving them a successful hands-on engineering experience.

In 2007, the SEI hosted a total of 134 participants on the campuses of VCU and VSU from nine different public school systems and all participants successfully completed the program. The SEI has touched the lives of more than 3600 minority students since 1978. The SEI's success rate is impressive. Based on responses to a survey carried out in 2000 by the *Richmond Area Program for Minorities in Engineering* Board of Directors, 99% of SEI participants have enrolled in college

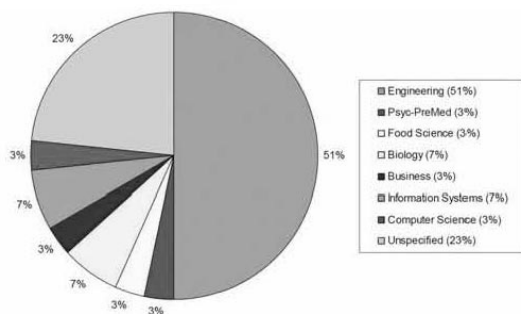


Fig. 1. Percentage college majors of SEI survey respondents.

immediately after high school graduation. Figure 1 shows the majors that the survey respondents chose. The SEI coupled with better understanding of the engineering and science profession has led to 51% of the SEI participants enrollment in engineering programs at colleges and universities, 26% have gone on to major in math or science related fields, while 23% remain undecided.

The most beneficial aspect of the SEI is in providing an accurate definition of engineering to middle and high school students. In addition, almost all of the SEI participants return in the following year to participate in the next phase and to see their new found friends, knowing that it's cool to be smart and interested in engineering, science, and technology.

To fully engage the students in engineering, we have developed a theme-based approach to the SEI. The theme-based approach starts with Phase I and ends with Phase IV. Phase I is designed for rising 7th and 8th graders. This phase introduces students to the practice of engineering by conducting projects, such as *Bridge Building and Failure Analysis*, *Circuit Analysis*, *Logic Blocks*, and *Solar Car Design and Racing* (see Fig. 2), and familiarizes them with engineering as a *profession*. Following this is Phase II, which is designed for rising 9th and 10th graders, exposes its participants



Fig. 2. Phase I participants on Warren truss bridge building.



Fig. 3. Phase II, Building and testing a colloid roller coaster.



Fig. 4. Phase III, Getting hands-on experience in the machine shop lab.



Fig. 6. Tour of Massey Cancer Building construction in downtown Richmond.



Fig. 5. Phase IVA, Programming and building Vex- robots.

to *Applied Engineering and Computer Concepts*, all of which supplement their robotics, *Roller Coaster Design*, *New Lego Mindstorm NXT*, *Parallax Boe-Bots*, and *K'nex Car Design and Racing Projects* (see Fig. 3).

After Phase II, the students then progress to Phase III, which is designed for *rising* 11th and *talented* 10th graders. Its participants are exposed to research opportunities and the exploration of scientific research as a potential career, and to prepare these students for undergraduate studies in colleges and universities as outstanding research students and leaders in the scientific community by conducting research in the area of *Nanostructures*, *Bioengineering*, *Bioinformatics*, and *Fuel Cells* (see Fig. 4). Phase IVA is designed for talented rising 11th graders. This phase combines two standard engineering curriculum offerings in *Engineering Graphics Design*, *Engineering Methods*, and *Vex Robotics* (see Fig. 5). Phase IV is the last phase of the SEI and it is designed for current 12th graders. The students are eligible to earn 2–4 academic credit for the completion of Virginia State University's Freshman Introduction to Engineering I and II, where they learn about engineering analysis, design, dimensions, methodology, mechanics, circuits, thermodynamics, fluid mechanics, and a Visual Basic application to solve technology-based problems.

It is critical that these activities associated with Phases I–IV of the SEI curriculum are designed to couple outreach with academics by familiarizing the participants with materials focus on learning and acquiring pre-engineering skills in design and problem solving that are needed to convey the skills and knowledge required for successful admission to undergraduate engineering programs and are current with engineering practice.

Every year, newly developed theme-based projects and tools are introduced to give K-12 students the opportunity to engage in hands-on engineering in the classroom. Before the programs start, the instructors have meetings with the director of the program and their teaching assistants. Topics to be covered under the selected theme during the SEI are discussed. Arrangements are made for the *Richmond Area Program for Minorities in Engineering* industrial partners to present lectures in the classroom and for the students to visit their corporations (see Fig. 6).

The theme-based projects employ a range of engineering disciplines, such as electrical and computer, mechanical and biomedical, and chemical and bioengineering. 'It's electric' is just an example of one of the SEI's themes, where students learn about basic circuit analysis, Van de Graaff generators, electromagnetism, and solar energy, to name but a few. These topics reinforce applied math, physics and engineering concepts. All the SEI activities aim to give students a chance to engage in authentic hands-on design, where they can create whatever they design. (Activities are detailed at www.rapme.org.)

IT'S ELECTRIC

The engineering economical landscape has shifted its focus to research skills, such as product design and development [4–5], where one designs and develops products through the manipulation

of their most fundamental units. The latest directions in engineering research has yet to reach the undergraduate curriculum and none the less the high school curriculum. It has also been noted that only a small proportion of high school graduates are prepared to pursue a career in science, technology, engineering, and math [6]. Put simply, a reorganization is needed in engineering instruction, and the curriculum is lagging behind engineering research and industry. For this reason, many have begun to call for the discipline to attempt to integrate more closely with educational and industrial research [7]. In the last two years, the *Richmond Area Program for Minorities in Engineering* has slowly increased its student's exposure to research experimentation and design in the area of Life Science Engineering (LSE) with the aid of faculties at Virginia State University and Virginia Commonwealth University. The integration of research and education with high school students helps them to be better prepared for undergraduate research activities in college and broadens the awareness and application of engineering research in local high schools.

Thirty-two students participating in the Phase III were organized into 11 teams. Five teams were assigned to research faculty members at VCU and the remaining six teams were assigned to VSU research faculty members. On a weekly basis, the students attended five 20-minute lectures given by their research faculty in an attempt to engage the participants in research experimentation and design [8–10]. At the beginning of the Phase III program, each team received a research notebook, an overview of the research project they are to conduct, and the specific aims of the project. Afterwards, the teams are provided with research training and they begin to conduct their research. The major components are teamwork, literature review, research proposal, statistical analysis, and prototyping.

The students can then put this experience toward a four-year engineering degree. Therefore, the research faculties and the high school students focus more effort on the lectures and its relation to research so that, ultimately, there is an overall increase in research productivity. Another important factor is that the research faculty has fewer different participants per summer and therefore the potential for a stronger faculty-participant relationship exists [8, 12–13]. Overall, existing studies show that an equal or better mastery and retention of material is obtained [8] through stronger faculty-student relationships. During the entire program, several projects have been conducted by the end of Phase III, such as Fuel Cells Design and Development, Nanostructures, Designing Ring Tones Base on the Manipulation of Frequency, and Development of a Jeopardy Game Prototype. The research faculty members evaluate the students performance based on their research accomplishment throughout the SEI and at the closely ceremony.

OBSERVATION MADE DURING LECTURES/ RESEARCH EXPERIMENTATION

In order to evaluate the effectiveness of the SEI Phase III program, a survey of participating students was conducted before and after the program. Before the program, SEI's 2006 survey found that 90% of the incoming middle and high school minority students did not know what engineering was, and the average participant primarily thought engineers built buildings or designed bridges. After the program, students defined engineers as people who looked at society's problems and tried to generate solutions. Of the students in SEI's 2006 session, 93% said they had gained a better understanding of what engineering is by the end of the program.

Some of the Phase III students' comments are featured below to highlight the success of introducing high school students to research experimentation and design.

- (a) The best part of this program was the faculty allowed us to use his research lab to conduct research based on the lectures presented. I enjoyed the lectures because they prepared me for the research experiments and I loved using the instruments, for example the Atomic Force Microscopy. That was neat.

All the participants felt that gaining hands-on experience with research instrumentation tools help them with understanding the importance of meeting the research objectives. Recognizing the importance of providing the students with a comprehensive picture of research is imperative that is why the faculty members collectively decided to present 20-minute lectures, which provide the fundamentals involved in conducting research. Moreover, these lectures brought real engineering experiences to the classroom. This was truly a unique research training process to gain real-life experience. One student mentioned in the survey that they enjoyed having short lectures and then immediately engaging in research training. Figure 7 is a photo taken in one of the research lab at the time the students were working as a team to carry out an experiment.

In this program I never got tired of taking notes because the lectures were so focused on the specific research which held my attention and I was excited about using what I've learned to do the research project selected by our team.

- (b) I understood conducting research because of the lectures, although reading technical and peer-review papers were a little above my head, the faculty was able to work with the team and explain the papers to us so that we can understand the research conducted and the statistical analysis performed in the paper.

By quantitatively defining and explaining statistical analysis, the students were able to analyze their



Fig. 7. Phase III, Getting hands-on experience in the Stem Cell Research Lab.

data. It would be difficult to present high school students with statistical methods without showing them how it relates to something they already know and understood. As a student wrote on the survey form:

Having research group meetings with the faculty and her research group and talking about each teams' project was intriguing. To be present and hear first hand what graduate students and research engineers thought of research was incredible.

- (c) Working within a team was the best part of the program for me, I like working with new people and making new friends.

All the projects available to the SEI Phase III participants covered a wide range of engineering aspects. The students were allowed to select which area they were interested in exploring. Completion of the research projects required the students to work in teams and share individual responsibilities. For example, the students had to go to the library and use the Internet to conduct literature reviews as a means of searching for relevant information pertaining to their research projects. They had to study together to gain an understanding of the subject. They also had to practice teamwork to prepare the research report and organize their PowerPoint presentations.

The SEI is definitely having an effect on girls and minority students. The SEI assessment found a very high retention rate for the girls coming from low-income households. In addition, female and black students had improved attitudes toward science after attending the SEI. Moreover, the SEI shows that pre-engineering camps can increase students' skills and positive attitudes about math,

science, engineering, and technology. Overall, the SEI allows and encourages greater opportunity for active and collaborative learning through research [9, 11, 12] and creates career paths to the sciences and engineering. In addition, the gap between engineering research and education becomes minimized through frequent application of engineering knowledge. The director of the program is now working together with the research faculty members to organize the teaching material in a textbook format to improve the teaching and research experience and to facilitate information dissemination with other programs.

CONCLUSION

The development of a pre-engineering program that effectively increases the size of the pool of high school students pursuing undergraduate studies in engineering, science, and technology has been described. It is evident that the *Richmond Area Program for Minorities in Engineering* plays a vital role in the engineering education for both middle school and high school students in Richmond, Virginia by addressing the need to provide its participants with both fundamental knowledge and real life experience in research experimentation. It was also observed that outreach plays a more important role in appealing specifically to female [14], and minority [15, 16] engineers. By connecting life experiences to subject matter in engineering and increasing the social relevance of the program, the SEI attracts and retains women in the field.

In order to increase the confidence or the self-perceived ability of the middle and high school participants in math and science [17–20], the SEI combined elements of research experience for K-12 education and teaching modules to yields a real impact on the SEI participants. Thus, advancing relevant project-based learning and enhancing the students understanding of engineering, science, and basic math concepts in a fun environment.

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