Success Institute:
Expanding the Pool of Under-Represented Minority Engineering Students

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Abstract — Engineering educators at CU-Boulder, teamed with community leaders from the wider metropolitan area, are working to expand the pool of underrepresented minority students who successfully study engineering, and thereby enhance their numbers in tomorrow's engineering workforce. CU's summer Success Institute resident workshops bring African-American and Hispanic high school students to campus for multi-day, hands-on engineering experiences. The intent is to spark the curiosity of under-represented minority students about science, math and engineering; enable them to pursue technical careers; and welcome them to campus. In a parallel program, parents attend the last day to learn about high school course selection, math appreciation, admissions, financial aid, peer pressure and other university life topics.

Index Terms — engineering outreach, K-12 outreach, minority engineering, minority K-12, diversity, high school students, outreach curriculum

INTRODUCTION

Working with the minority community, the University of Colorado at Boulder's College of Engineering and Applied Science has implemented a summer Success Institute to bring African-American and Hispanic high school students to campus for multi-day, hands-on engineering experiences. The intent of CU's Success Institute (SI) is to expand the future pool of under-represented minority students in the engineering student body by sparking the curiosity of these students about science, math and engineering, introducing them to the university world, and preparing them to pursue technical careers.

Through a hands-on introduction to the challenges and joys of engineering in the world-class Integrated Teaching and Learning (ITL) Laboratory, the same students return to campus each summer of their high school years to explore increasingly challenging engineering projects (see Figure 1). Student SI participation varies by grade level; participants spend two to five days on campus engaged in hands-on projects that explore general engineering principles and culminate in presentations to an audience of their parents and peers.

Parents are included in a companion program that helps them support, guide and encourage the full potential of their teenager. Program success is measured by students' admissions to a higher education program after high school graduation.

FIGURE 1.
SUCCESS INSTITUTE 2000 PARTICIPANTS IN THE ITL LABORATORY.

MOTIVATION AND VISION

The demographic composition of the U.S workforce is expected to shift dramatically between 1998 and 2008, with the Hispanic labor force projected to grow by 37%, the African American labor force by 20% and the Caucasian labor force by 10%. While African American, Hispanic and Native American people collectively comprise almost a quarter of the U.S. workforce and 30% of the college-age population, they received only 12% of the undergraduate engineering degrees awarded in 1999 [1]. This is particularly alarming considering that the demand for technically trained professionals is steadily growing, and that we are in the midst of dramatic demographic shifts. Put simply, as a nation we must increase the numbers of underrepresented minority people in the engineering workforce if we are to continue to meet the demands of a technological society.

National demographics are mirrored in Colorado. In fall 2000, minority students accounted for 32% of Colorado’s
public school students. However, the 2000 graduation rates for Colorado’s public school minority students (69% for African American, 65% for Hispanic and 63% for Native American) lagged significantly compared with Caucasian (85%) and Asian (85%) graduation rates [2].

Low expectations, a lack of understanding of mathematics and science disciplines and opportunities, insufficient academic preparation, ethnic isolation in higher-level math and science classes, a lack of mentors and absence of peer support are characteristics that place students at risk of not furthering their education and deter them from pursuing a track that will prepare them for a college education in mathematics, science and engineering. A 1994 Harris poll [3] based on interviews with 2,500 public-school 5th-11th grade students concluded that so few minority high school students choose math courses because:

- Four out of five students make course selections by themselves,
- Only one third of parents help (or plan to help) choose their children’s math courses,
- More than half the students intend to drop math at the first opportunity, and
- While 88% of students believe advanced math is required for many jobs or careers, only 33% of minority and 55% of non-minority students understand that the lack of these math skills limits their job opportunities.

An awareness of these trends led to the creation of the first Success Institute. In 1998, a team of engineering and math educators from CU-Boulder met with a group of African American community leaders from Denver to develop a shared vision. They envisioned a program that would enlarge the pool of under-represented minority students who would be successful in CU’s College of Engineering and Applied Science. In response, the Success Institute was created.

**PROGRAM GOALS AND COMPONENTS**

The Success Institute (SI) program goal is to involve and inform underserved students about their potential for further education and a career in engineering and technology and to make them feel welcome at CU-Boulder, thereby expanding the pipeline of qualified minority students studying math, science and engineering at the college level. This intent is served by providing a program that:

- Increases parents’ awareness of technological career opportunities, financial aid opportunities, and the college application process;
- Increases students’ awareness of their opportunities in higher education and acquaints them with an excellent local institution of higher education; and
- Culminates in a practical experience that increases students’ technical abilities.

Program goals are met through specific activities. Team-building activities build a sense of camaraderie and provide a foundation for subsequent group projects. The computer-based data collection and analysis experience increases students’ technical knowledge. The hands-on engineering activities increase their comfort with technology and encourage a positive attitude towards engineering as a field of study. Practicing oral presentations in a safe environment boosts the students’ confidence in technical presentation skills and their ability to perform in a college or professional atmosphere. Minority faculty and student mentors provide role models that link the student to the university and industry worlds. Spending meaningful time on campus acquaints the students with the college environment in a purposeful way.

During the summer SI program, the nature of student participation varies by grade level:

- The rising 9th grade students (having completed 8th grade) are on campus from Friday morning through Saturday evening exploring on hands-on projects that probe numerous general engineering principles and culminate in presentations to an audience that includes their families.
- Rising 10th grade students also arrive early on a Friday morning and leave Saturday evening. They explore more advanced thermodynamics and heat transfer engineering activities (see Figure 2).

**FIGURE 2.**

10th grade students display the working solar ovens they created and tested by baking brownies.
• Rising 11th grade students arrive on a Wednesday morning and stay through Saturday evening. Teams each build a “smart” room, all of which are combined into a “smart” house at the end of the project.
• Rising 12th grade students arrive on a Tuesday morning and stay through Saturday evening. Teams complete an energy-based design/build project, typical of engineering, culminating in an Expo for their families.

Students fill out a detailed application form, and provide a school transcript and teacher / counselor recommendation letter. In some cases, we consult with the referring teacher(s) to gain a full understanding of a student’s skill level. Then, the activities are scaled to be age-appropriate, and all project instructors are educated in a curriculum training session as to the students’ skill levels, SI expectations and anticipated program outcomes.

**PROGRAM ADMINISTRATION**

The *Success Institute* has expanded greatly from the 14 pioneers in 1998, adding more challenging curriculum for subsequent grade levels. Return rates have been high, and any vacancies are filled with new students. In 2001, the *Institute* achieved its first complete cycle, with students in all four grade levels (see Table 1).

The *Institute* has expanded geographically as well. During the first two years, the focus was on students, primarily African-Americans, from the Denver public school system. As the success of the program generated more support, expansion tapped other Colorado school districts, reaching Hispanic and Native American students. Recruitment from three school districts results in a diverse mixture of urban, suburban and rural students.

Expansion brought its own set of challenges and valuable lessons. In 2000, 9th, 10th, and 11th grade students all participated during the same week. This resulted in logistical problems, as there was not enough staff, space or curricula to attend to everyone. In future summers, the 9th and 11th grade students will attend together during one week, while the 10th and 12th grade students will attend during a different week. This makes sense since the overlap of the two groups during the same week is only on Friday and Saturday, and the subject areas are compatible. For example, the 10th grade project focus is energy, while the design/build project for the 12th graders is energy-based. We have also learned that scheduling should not compete with other activities of which the students may be involved, such as other enrichment programs and athletic camps.

Additional logistical challenges include registration details. As enrollment increased, the most impacting problem became “no shows.” Since all dormitory rooms must be paid in advance, and the presence of an appropriate number of mentors and faculty members are arranged based on the expected attendance, a 21% no-show rate in summer 2000 created an unacceptable loss of resources. In response, a non-refundable $25 fee was imposed in 2001 to better ensure commitment. A system of stipends for successful completion was also instituted, rewarding returning students and providing some compensation for income loss. In addition, more students also increased the instances of behavioral problems, so a code of conduct, signed by both the students and their parents, became required. As a further sign of having become a large-scale summer program, medical information sheets and waivers were instituted.

Undeterred, the *Institute* intends to expand even further. Table 1 summarizes the anticipated future participation as we reach a steady state of 48 students per cohort.

**PARTICIPANT RECRUITMENT**

Students are selected based on nomination by their math and science teachers, or community agencies (i.e., Mathematics Engineering Science Achievement [MESA], Denver Educational Excellence Program [DEEP], Junior Engineers Tomorrow’s Scientists [JETS]), which sponsor in- and after-school activities that promote interest in math, science and engineering. These contacts ensure participation of success-oriented minority students who possess the desire and aptitude to pursue studies in math, science and engineering.

Continuous contact with existing *SI* participants and their school liaison is critical to encouraging them to return each year. To recruit new 9th grade students, a multi-media presentation was created for middle school talks conducted by schoolteachers, counselors, *Institute* alumni and *Institute* program and university representatives. Student applications require a parent signature and their agreement to attend the parent Saturday program.

**TABLE 1.**

<table>
<thead>
<tr>
<th>Summer of:</th>
<th>9th Grade</th>
<th>10th Grade</th>
<th>11th Grade</th>
<th>12th Grade</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998 (actual)</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
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<tr>
<td>1999 (actual)</td>
<td>15</td>
<td>20</td>
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<td>35</td>
</tr>
<tr>
<td>2000 (actual)</td>
<td>24</td>
<td>21</td>
<td>23</td>
<td></td>
<td>68</td>
</tr>
<tr>
<td>2001 (projected)</td>
<td>48</td>
<td>48</td>
<td>24</td>
<td>24</td>
<td>144</td>
</tr>
<tr>
<td>2002 (projected)</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>24</td>
<td>168</td>
</tr>
<tr>
<td>2003 (projected)</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>192</td>
</tr>
</tbody>
</table>
Potential 9th grade SI students visit the campus for a half-day field trip during spring of their 8th grade year to engage in a number of engineering-oriented activities as well as mingle with university engineering students. Interested students complete contact cards, which allow us to provide further information to their family. Other recruitment activities include meetings with community leaders, trips to campus for the MESA Spring Fling and the fall and spring semester undergraduate engineering Design Expos.

SUCCESS INSTITUTE PARTNERS

The Success Institute is a collaboration between two programs in CU’s College of Engineering and Applied Science. Originally the vision of a retired African American engineer from IBM, it grew to include the Multicultural Engineering Program and the Integrated Teaching and Learning Program. The shared commitment of these programs and the minority community is to expand the horizons of underserved students by welcoming them to a university environment and showing them the possibilities of pursuing careers in engineering and technology.

MEP Profile

The Multicultural Engineering Program (MEP) was established in 1973 as a minority student engineering program. MEP’s mission is to recruit, retain and graduate minority engineering students. Centered on the philosophy of “Building Community,” MEP provides scholarships, a five-week summer bridge program for first-year students, a leadership course, academic excellence workshops, academic intervention, personal and academic advising, tutoring, career and internship assistance, and a student study and resource center.

Today, 194 minority students are enrolled in the College, 7.5% of the student population. Over the past five years, an annual average of 35 minority engineering students received their Bachelor of Science degrees. The Building Community retention model has achieved steadily increasing academic performance of its first-year students, dramatically increasing retention and graduation rates to 67%. A recent NACME retention study ranked the College seventh in the nation for retention of minority engineering students, achieving nearly double the national retention rate of 36.5% [4].

ITL Program and Laboratory Profile

The Integrated Teaching and Learning (ITL) Program was initiated in 1992 to enhance hands-on, team-oriented opportunities for undergraduate engineering students, capitalizing on the effectiveness of learning by doing. The ITL Laboratory (ITLL), a state-of-the-art, hands-on learning environment used by approximately 2,800 undergraduate students annually, supports the summer K-12 outreach program. The ITL leadership is committed to engineering outreach, expanding public and K-12 awareness of engineering and technology and making it accessible and understandable.

The unique learning environment of the ITL Laboratory includes design studios, open experimental laboratory plazas equipped with data acquisition capability, electronic and mechanical fabrication centers, team work areas and a captivating array of interactive exhibits that make engineering come alive for students. More than 300 sensors integrated into the building continuously record the ITLL’s “pulse,” with the data accessible via Internet. Because the College’s undergraduate programs are concentrated into a nine-month academic year, the ITL Laboratory is an ideal summer venue for a K-12 engineering outreach program.

Community Advisory Panels

Critical to the successful evolution of the Success Institute is involvement of key people from the local community and school districts. Advisory panels, composed of passionate educator and industry professionals who provide a range of assistance including policy recommendation, student participant recruitment, industry panel participation and summer student group mentoring, formalize a link to the community.

CURRICULUM ELEMENTS

Program activities at the Success Institute vary by grade level. As the students return each summer to the CU-Boulder campus, an increasingly challenging curriculum awaits them. Their first encounter with engineering allows them to experiment with a hands-on experimental “module,” and their final experience challenges them to design and build a product from scratch.

Student Curriculum

The 9th grade students arrive by bus early in the morning, greeted by mentors and faculty. The students are encouraged to sit next to participants who they don’t know, and the ride provides a good opportunity for structured icebreaker activities. After checking into the dorms, students are placed into groups for team-building activities, followed by an introduction to laptop computers, and word processing, spreadsheet and presentation software. A team challenge then sends them on a scavenger hunt all over campus using Global Positioning Systems (GPS) technology. This accomplishes three objectives as the participants:

• Obtain experience using technology,
• Become familiar with the campus, and
• Expend some energy (essential at this age!).

Session

October 10 - 13, 2001 Reno, NV

31st ASEE/IEEE Frontiers in Education Conference
Evening activities include math games conducted by a faculty member and graduate students, and panel discussions with current undergraduate engineering students of color.

Early the second day, 9th grade student teams are matched up with faculty members and each team works on a different hands-on experimental module. These include experimenting with sound theory using guitars, and measuring viscosity and density employing Reynolds’ creeping flow theory. They use computers and software for data acquisition, plotting and analysis, as well as presentation preparation. Teams ultimately present their findings to an audience of their parents and peers.

The 10th grade curriculum follows a similar structure. They learn about power consumption technology before exploring the Engineering Center to test and compare power consumption of equipment and appliances. Again, they use technology, become familiar with campus facilities, and are physically active. Evening activities include a panel discussion and a challenge, led by a civil engineering professor, to re-design the leaning tower of Pisa so that it doesn’t lean.

On the second day, the 10th grade students explore numerous experimental modules that incorporate the theme of energy — one team compares different solar oven designs, while another measures the power of different water turbine designs. Data analysis follows, and the day ends with a presentation of experimental findings.

Project-based engineering starts with the 11th grade curriculum. The students are challenged with a project that must be completed and presented at the end of four days. Interestingly enough, this is the first year in which the students appear to feel comfortable in the ITL Laboratory — their attitude change is apparent when they stride in the building and immediately make themselves at home. The teams design “smart” rooms, all of which will later be combined into a “smart” house (see Figure 3). Teamwork becomes important, as students learn to function both within their team, and with other teams. Social activities are kept to a minimum, as the bulk of the time is spent designing, building, and testing the projects, often well into the evening.

Finally, as 12th grade students, they design and build a project from scratch. In five days, they create a miniature solar vehicle, which requires learning about gears and basic electronics, and becoming skilled in the use of SolidWorks®, a software program for machining. In addition, they learn the fundamentals of aerodynamics, energy conservation and alternative energy sources, in order to produce a working car that they take home to keep.

The increasingly challenging curriculum helps the students to become gradually acclimated to engineering expectations and processes, as they build on the previous years’ skills, growth and creativity. By the time 12th grade students undertake a more open-ended project, they are comfortable with the technology, able with the skills, and eager to experience the design/build process.

Parent Participation

On the Saturday of each Institute, a parallel program invites the parents to learn ways to support, guide and encourage the full potential of their children. Through panel discussions, parents discuss how to enable their children, discover opportunities for financial aid, and become familiar with the college admissions process. Other topics in the parent track include study skills, approaches to peer pressure, high school curriculum selection advice and college financial planning.

Industry Participation

One request from both parents and community members is to provide an opportunity for the students to interact directly with real-world professional engineers from outside the university. Therefore, Saturday workshops include an industry panel, at which minority professional engineers discuss their careers, how they got where they are, what an engineering degree brings to them, etc. In addition, industry mentors volunteer from organizations such as IBM Corporation, Level3 Communications, the Department of Energy and Amgen, Inc. These mentors directly guide a team of students throughout the program, not only through the experiments but also advising them about engineering career opportunities.

EVALUATION AND ASSESSMENT

A continuous improvement model is applied to all K-12 outreach initiatives. Feedback assessment methods are employed with students and parents during and at the end of Institute sessions.
of each Success Institute. Pre- and post-Institute skill evaluation surveys are administered to 11th and 12th grade participants. Questionnaires provide feedback that is used to improve the Institute for future summers. Annually, a program review is conducted to evaluate the overall program effectiveness and make modifications towards improvement the next year.

Is the Success Institute successful? The answer from students and parents who participate is a resounding “yes.” Anonymous questionnaires solicit student and parent feedback, and ask for suggested improvements.

Student Feedback

The most frequent student suggestion for program improvement was to extend it for more days. A common theme expressed by the students was that they liked the Institute because they learned and also had fun doing it — a wonderful measure of success. Specific student comments included:

- “I liked the experiments and the GPS scavenger hunt best because they both were very fun to do.”
- “Learning about electricity and power was the best part of the workshop.”
- “What I like best about the Institute is how we can improve and learn science and engineering.”
- “I got to work on computers with college students and teachers that were really nice.”
- “Students from Boulder talked to us about how science and math can get you different places.”
- “Everyone was able to talk and give presentations and be comfortable with it.”

Many students reported that what they liked best about the Success Institute were the hands-on projects and “cool experiments.” Students clearly like staying in a college dormitory. Many students reported that they liked “meeting new people and learning about teamwork.” And, to our surprise, they thrived on making computer-based presentations.

Parent Feedback

In response to parent feedback from the pilot program, the parent workshops were expanded. Every parent expressed an interest in his or her high school-age child continuing to participate in future years. Other parent comments included:

- “The Success Institute provides information to the students regarding engineering and science. Oftentimes middle and high school students don’t have access to this information.”
- “It allows kids to get some familiarity with a college campus.”
- “Providing exposure to the student to help them to have, and make, choices in the area of higher education is the best aspect of the Success Institute.”
- “The Success Institute has provided me with the information I need to help my child with her future educational need.”

One parent summed up his/her impressions by stating, “This program at CU is making a difference in the lives of young people…the Success Institute is actually concerned about children and their future.”

CONCLUSION

The biggest challenge facing this outreach initiative is its sustainability. To be successful, it demands time, funding and a constant source of committed volunteers. We actively fundraise for the program’s future. Fortunately, the Success Institute outreach initiative is a high fundraising priority for the College. Since 1998, in addition to support from the National Science Foundation and the Colorado Commission on Higher Education, grants have also been received from the New Century Energies Foundation, the Hewlett Packard Foundation, the Department of Energy, the CU Outreach Committee, the Colorado Institute of Technology and a private engineering alum.

We are hopeful that we will reach our goals. In the next year, our inaugural class of Success Institute participants graduate from high school, and we eagerly await their choices of college and career.

REFERENCES


