

AC 2010-1420: GO FOR AEROSPACE! HIGH SCHOOL RECRUITMENT PROGRAM: PRELIMINARY OUTCOMES, LESSONS LEARNED AND FUTURE DIRECTIONS

Michele Dischino, Central Connecticut State University

Dr. Dischino is an assistant professor in the Technology and Engineering Education Department, teaching courses for pre- and in-service K-12 technology educators. Dr. Dischino received her Ph.D. in Bioengineering from the University of Pennsylvania in 2006 and her B.S. in Mechanical Engineering from Manhattan College in 1992. Before pursuing her doctorate, she gained several years of industry experience. Her doctoral research was conducted in the McKay Orthopaedic Research Lab at UPenn, where she explored strategies to improve the outcome of tendon injuries through engineering. As a graduate student, Dr. Dischino became heavily involved in educational outreach work with inner-city public school students in Philadelphia. It was through this work that she realized her passion for teaching technology and engineering concepts at all levels and encouraging students to achieve their full potential in these fields. She is currently a member of the American Society of Engineering Education, the International Technology Education Association and the Association for Science Teacher Education, as well as a Champion Board Member of the Connecticut branch of the National Girls Collaborative Project and Board Member of the CT Pre-Engineering Program, a non-profit organization whose mission is to help underrepresented students explore their full potential in STEM. Dr. Dischino and her colleagues were selected as winners of the 2009 ASEE K-12 Best Practices Panel, Middle School Category.

Nidal Al-Masoud, Central Connecticut State University

Dr. Al-Masoud, Associate Professor, earned his Ph.D. in Mechanical Engineering from The University at Buffalo, The State University of New York in 2002. Dr. Al-Masoud has taught at both graduate and undergraduate level courses at University at Buffalo, he joined Central Connecticut State University as an Assistant Professor in 2003. At CCSU, he teaches courses at all levels in the three major areas in mechanical engineering, namely: mechanics, Thermo-fluid, and Control Systems and Dynamics. Dr. Al-Masoud research interests are in the fields of Control Systems and Dynamics, HVAC systems, and Engineering Education. He has numerous journal and conference proceeding publications in the aforementioned area, and was the winner of the ASEE Mechanics Division Best paper Award in 2006. He has extensive experience in Heating Ventilation and Air Conditioning Systems (HVAC) design. Dr. Al-Masoud is very active in many Professional Societies. He serves on the Board of Directors of American Society of Mechanical Engineers, Hartford Section; he is also the Faculty advisor of CCSU-ASME Student section. He is a member of the American Institute of Astronauts and Astronautics (AIAA), IEEE, ASEE.

Peter Baumann, Central Connecticut State University

Dr. Baumann is an Associate Professor of Engineering at CCSU. His industrial experience spans 20 years. He is Past Chairman of American Society for Testing and Materials (ASTM) Committee B7 and is on his local ASM International chapter's Board of Directors. Dr. Baumann received a B.S. in Metallurgy at Penn State, earned an M.S. from MIT Mechanical Engineering, and completed a Ph.D. in Materials Science at Polytechnic University.

Viatcheslav Naoumov, Central Connecticut State University

Dr. Naoumov, is an associate professor in the Department of Engineering, and teaches propulsion, aerodynamics, fluid mechanics, instrumentation and senior capstone design classes for engineering technology and mechanical engineering (including aerospace specialization) students. Dr. Naoumov has extensive aerospace experience, having worked with both the Russian and French Aerospace Agencies, and with the Mechanical, Aerospace and Biomedical Engineering Departments at the University of Tennessee (UT). While at UT, he supervised engineering students in the design and construction of lunar vehicles in the NASA Great Moon

Buggy Race Project, and initiated the NASA Reduced Gravity Student Flight Opportunities program. Since joining the CCSU faculty, Dr. Naoumov has spearheaded the development of a NASA Moon Buggy program at the University.

Zdzislaw Kremens, Central Connecticut State University

Zdzislaw B. Kremens, Ph.D., D.Sc., has been Dean of the School of Engineering and Technology since 1998. Previously, he was interim dean of the School and a visiting professor from the Technical University of Wroclaw in Poland, where he was a professor and vice president of academic and student affairs. Dean Kremens oversees a School that has been designated a “Center of Excellence” by Connecticut’s Board of Governors of Higher Education. He has been instrumental in strengthening and expanding the School’s academic offerings, which include bachelor’s and/or master’s degrees in engineering, engineering technology, technology, technology and engineering education and biomolecular sciences. Dean Kremens has authored or co-authored three books and more than 60 papers about the control, simulation, and analysis of electric power systems. A professor of electrical engineering, specializing in electric power systems, he also teaches courses in telecommunication, electronics, and electro-mechanical converters. Dr. Kremens has been active in many academic and scientific organizations, including the Institute of Electrical and Electronics Engineers (IEEE).

Go For Aerospace! High School Recruitment Program: Preliminary Outcomes, Lessons Learned and Future Directions

Introduction

Need for STEM Talent in the U.S. and National Statistics

Long-term growth in the number of positions in science and engineering has far exceeded that of the general workforce, with more than four times the annual growth rate of all occupations since 1980.² Recent occupational projections from the Bureau of Labor Statistics³ forecast that total employment in engineering fields will grow by approximately 10% between 2008 and 2018. While the outlook varies by discipline, aerospace engineering is expected to follow this trend in response to a growing demand for new technologies and new designs for commercial and military aircraft over the next decade. Thus, the employment outlook for aerospace engineers appears favorable.

In spite of these promising job prospects, recruitment for science and engineering programs is a real challenge for most universities nationwide. According to the recent Congressionally requested report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, in South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore, 67%. In the United States, the corresponding figure is only 15%.⁴ This is one of the most serious issues our nation will face over the next decade, as the current science and technology workforce retires without a pipeline of workers to replace them. The aerospace industry is one such example of this looming crisis. Of the 600,000+ aerospace workers employed in 2006, ~26% are eligible for retirement this year, but only 40,000 graduating engineers are qualified to work in the industry.⁵

Although the number of degrees granted in aerospace engineering has begun to increase after many years of decline, new graduates continue to be needed to replace aerospace engineers who retire or leave the occupation for other reasons.³ If the United States is to maintain its competitive edge in the global economy, the pipeline of interested and qualified students prepared to enter STEM careers must be increased. Yet recent results from a survey by the American Society for Quality (ASQ) revealed that more than 85% of students today are not considering careers in engineering and that more parents encourage their daughters to become actresses than engineers. Forty-four percent (44%) of survey respondents cited a lack of knowledge around engineering as the top reason they would not pursue such jobs. Another 30% listed the “geek” perception as their top reason, indicating that “engineering would be a boring career,” according to the ASQ.⁶

Equally alarming, international comparisons of student mathematics and science performance indicate that U.S. students scored below average among industrialized countries.⁷ Out of the 57 countries participating in the 2006 Program for International Student Assessment (PISA) examination, which is designed to assess students’ abilities to apply scientific and mathematical concepts to real-world problems, U.S. 15-year-olds scored lower than 23 and 31 nations in

science and math literacy, respectively.⁸ Furthermore, the retention rate for engineering students is one of the lowest among all college majors; one-third of all U.S. students intending to pursue engineering switch majors before graduating.⁴

Demographic Disparities in Math and Science Achievement

According to the National Science Board's *Science and Engineering Indicators 2008*,⁷ there are significant racial and ethnic gaps in science and mathematics performance, as evidenced by studies that follow the same groups of students as they progress through school. These studies "reveal performance disparities among demographic subgroups starting when they enter kindergarten... Although all subgroups made gains in mathematics and science during elementary school, the rates of growth varied and some of the achievement gaps widened." Similar gaps were observed in rates of immediate college enrollment, with Black and Hispanic students as well as those from low-income and poorly educated families who trail their white counterparts or those from high-income and well-educated families.⁷ Connecticut has the largest achievement gap between urban and suburban school districts in the country, with the greatest concentration of population in the cities and ring-towns. The largest cohort of our future workforce is comprised of these most at-risk students.⁹

The outlook is also bleak in higher education. Nationwide statistics¹⁰ show that in 2003, 68.3% of engineering degrees were awarded to Caucasians, 14% to Asian-Americans, 5.1% to African-Americans, 5.4% to Hispanic students and 7.2% to others. It is important to note that since 1999 there has been a declining trend in the number of Hispanic and African-American students among all engineering graduates. At the same time, the percentage of bachelor's engineering degrees awarded to women is around 20%, another indication of the declining trend. For women in mechanical and aerospace engineering the numbers are only 13.2% and 18.8% respectively.

Effects of Early Experiences on Interest, Retention, and Success

The idea to engage students in early, hands-on experiences as an authentic scientist or engineer is not a new one. However, it is only in recent years that extensive, formal research examining the outcome of these opportunities has emerged. According to the *2008 Science and Engineering Indicators*, "There is now a growing body of literature that examines the results of such efforts and analyzes them for their effect on at least one of the following outcomes: student attitudes toward science, student research skills, student confidence in his or her ability to become a scientist or engineer, and retention of students within the field."⁷ In general, these studies have shown increases in students' interest in and understanding of the research process and the strategies and tools that scientists use to solve problems, and a broader sense of career options in the field.¹¹ A number of studies found that students with a broader range of abilities as well as underrepresented minority students were more likely to stay in or switch to a science or engineering major and pursue science or engineering graduate education because of an early experience with a working scientist or engineer.¹²⁻¹⁶

Local Aerospace Industry Workforce Needs

Connecticut has relied heavily on defense and advanced manufacturing industries to fuel the statewide economy with high quality, high paying jobs for several decades. Now, we are facing a critical window for economic transformation from an industrial base to 21st century high-tech

occupations. High-technology companies form a large, growing sector of the state's economy, with growth in STEM occupations projected at 13.5% from 2004 to 2014, compared with Connecticut's overall projected employment increase of 8.5%. The highest numbers of annual openings in STEM occupations are projected in the computer science and engineering fields.¹⁷

There is a particularly strong need for graduates proficient in the area of aerospace engineering in Connecticut. Several large, internationally known companies employing aerospace engineers maintain a significant presence in the State, including General Dynamics and United Technologies Corporation and its subsidiaries: Sikorsky Aircrafts, Hamilton Sundstrand, and Pratt & Whitney. Additionally, there are a significant number of small to medium sized high-tech manufacturing companies in Connecticut that are a critical component of the aerospace and defense industries supply chain. However, recent statistics from the Connecticut Department of Labor in aerospace, computer and electrical engineering¹⁸ suggest a gap between the projected availability of engineering jobs and the number of qualified graduates to fill them.

In a 2008 interview, the Commissioner of Higher Education in Connecticut drew attention to this gap, noting that while an estimated 754 jobs engineering jobs would become available in the state that year, only 614 qualified graduates would be produced to fill them,¹⁹ a condition worsened by the known outflow of engineering graduates from the state.²⁰ According to regional graduate retention data,²⁰ only 27% of graduates intend to stay in the area, while 45% plan to leave after graduation. This makes the shortage of engineers even more severe than statistics of openings versus graduates illustrate, and further highlight the importance of retaining young engineers in Connecticut.

The Connecticut Department of Labor compared the number of graduates in Connecticut with the number of annual openings for each occupation. The engineering/science/technology occupations were listed as having the best opportunities for employment. Among these occupations, mechanical engineering and related specializations ranked number one, with 511 annual job openings but only 268 graduates, indicating that if all graduates sought employment locally, only ~50% of openings would be filled, a condition worsened by the known outflow of engineering graduates from the state. According to regional graduate retention data,²⁰ only 27% of graduates intend to

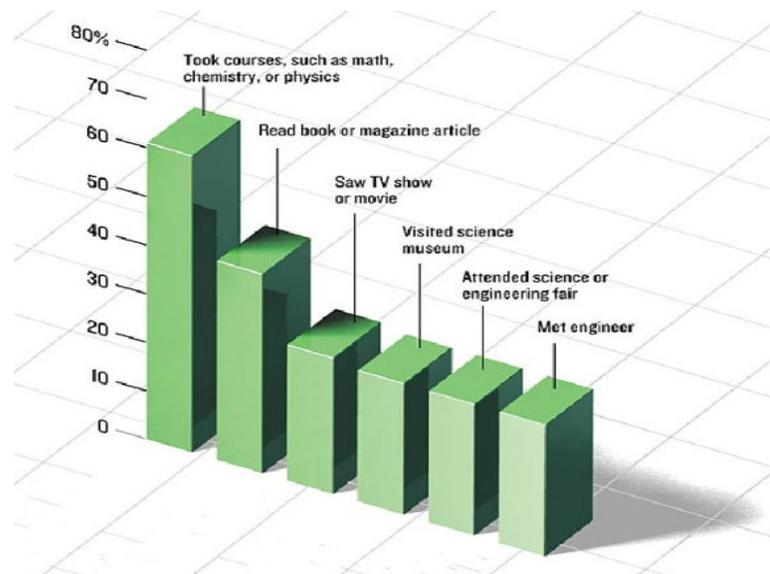


Figure 1. Activities that inspired survey respondents to consider being an engineer/technology professional.¹ (Source: The Response Center, a market research firm in Fort Washington, Pa., conducted the survey for IEEE Spectrum and IEEE-USA. An e-mail questionnaire was sent to about 2000 higher-grade and 2000 student IEEE members selected randomly. Data was collected between 3 and 16 December 2003. A total of 830 members responded, including 427 higher-grade and 403 student members, for a 21 percent response rate. More data from the survey is available at www.spectrum.ieee.org.)

stay in the region, while 45% plan to leave after graduation. This makes the shortage of engineers even more severe than statistics of openings versus graduates illustrate.

To help meet our growing workforce needs, it is essential that higher education and industry join together and reach out to students to encourage their interest in the sciences, and provide mentoring and support as they graduate and go on to college. Central Connecticut State University (CCSU), with its cadre of well-qualified faculty, its central location, and its close linkages with local industries and schools, can provide this mentoring and outreach and specifically, can encourage student interest in mechanical/aerospace engineering and provide a quality undergraduate program. According to Connecticut State University System Statistical Reports, over 85% of CCSU's undergraduates and 91% of its graduate students remain in the state, positioning the University as a key player to alleviate shortages in the mechanical engineering/aerospace specialty areas.

Program Description

Overview and Objectives

CCSU received funding from NASA to conduct an innovative, extracurricular program, "Go For Aerospace!" (GFA). This year-round program for high school students and teachers is designed to foster students' interest in and readiness for participation in aerospace engineering and related fields. The GFA program has the following specific goals:

- Expose high school students, especially those from underrepresented groups, to career paths related to aerospace engineering;
- Conduct research about the effects of the GFA program to enable rigorous assessment of this and other student and teacher outreach projects; and
- Contribute to the research knowledge base about STEM career preparation through dissemination of information about the program and its resources, and insight gained from the program's development and implementation.

Selection Process

The selection process is an extremely important part of the entire project. Results from surveys of technology students (Figure 1) indicate that math and science teachers can have a significant impact on the decisions of prospective engineers. This important fact informed the strategy that we use to recruit each cohort of students. We began by first assembling the math and science supervisors from several high-need school districts in order to provide them with an overview of our new program and the desired profile of qualified student candidates, i.e., high school juniors with high potential in math and science who are undecided about their college plans. A recent survey of college graduates showed that 48% of those who chose to pursue engineering did so during grades 11-12.²¹ The district supervisors then passed this information along to their high school math and science teachers, who proceeded to nominate students for the program using application forms we specifically developed for GFA.

Based on their recommendations, 30 high-achieving high school juniors were selected for the 2008-2009 cohort (demographic data provided in Figure 2) and on November 17, 2008, a kick-

off dinner was held at on our campus that included a keynote lecture from Coast Guard Aviator and NASA Astronaut, Captain Daniel C. Burbank. Also in attendance at the kick-off were the university's President, Provost and special guests from industry and public education, as well as many of the students' nominating teachers and parents. In a recent installment in the Harvard Family Research Project's series of evaluation briefs, "Issues and Opportunities in Out-of-School Time," Lauver et al. list effective outreach to families among the key strategies for getting students into programs and sustaining their participation.²² This underscores the importance of parent involvement.

Spring 2009

An overview of the GFA Program is shown in Figure 3. During spring 2009, students participated in four spring sessions, the aim of which was to provide students with an informed understanding of the engineering profession in general, as well as an appreciation of what a typical engineering job in the aerospace industry might involve. One Friday per

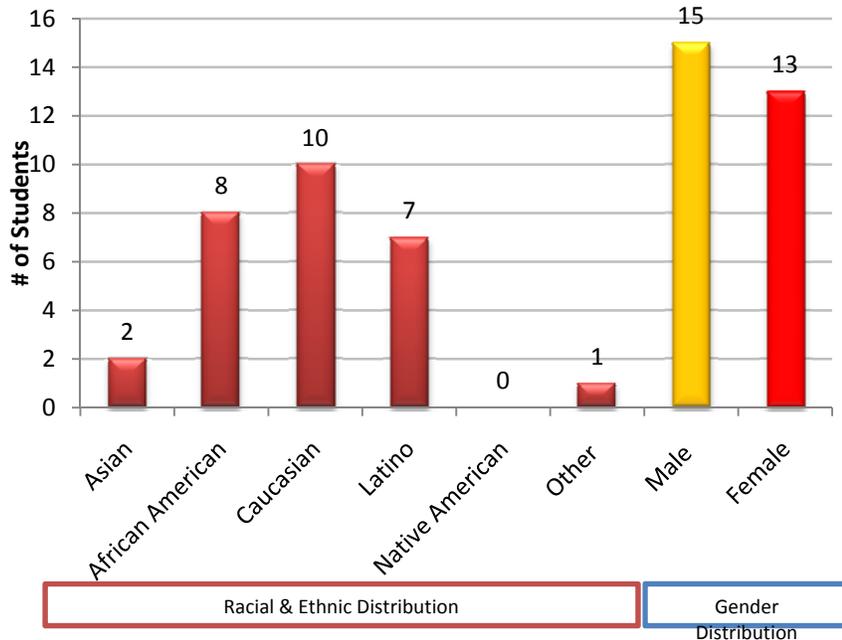


Figure 2. Race/ethnicity and gender distribution of Go For Aerospace! participants.

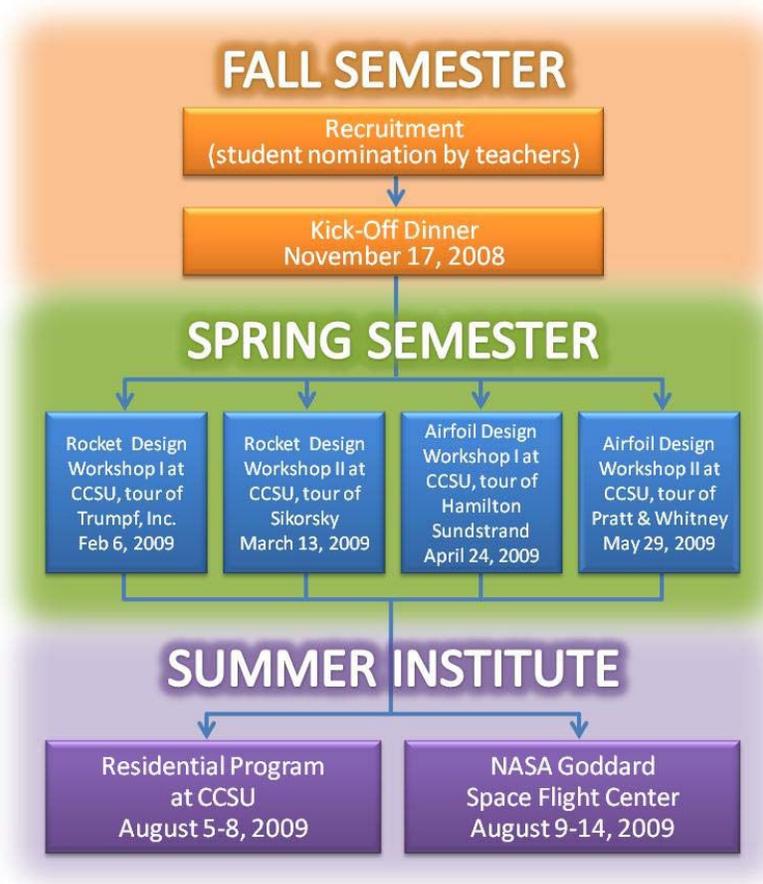


Figure 3. Go For Aerospace! Program at a glance.

month between February and May, students were transported from their respective high schools to our campus, where they spent the morning working with university faculty and students on projects related to mechanical and aerospace engineering. After lunch on campus, the students visited industrial aerospace facilities to tour research and manufacturing labs and speak with practicing engineers. Each month the students visited a different company.

Two workshops were developed and carried out with the high school students during the spring semester. Each was divided into two sessions so that the first workshop took place over the first two visits and the second occurred during the latter half of the semester (see Figure 3). All workshops began with a brief lecture introducing students to the relevant theory and its applications.



Figure 4. Undergraduate assistant helps GFA student prepare her rocket for the launch competition.

1) Rocket Design and Building Workshops I and II (February, March, 2009)

Teams of two students calculated the performance (thrust, altitude and flight time) and main geometrical parameters of a rocket using NASA's Rocket Modeler software. They next used these parameters to design and build water bottle rockets from 2-liter soda bottles. The final event of the workshop was a launch competition (Figure 4), in which altitude was measured and compared with the calculated (theoretical) altitudes. Student teams received awards for the highest altitude and best correlation between experimental results and theoretical predictions.

2) Airfoil Design and Testing Workshops I and II (April, May, 2009)

The objective of this workshop was to introduce students to the main principles behind flight dynamics. Using the fundamental laws of high school physics along with the concepts of lift and drag, students learned which wing and airfoil designs provide high lift and low drag. The main parts of airplanes and their functions were also introduced. These theoretical concepts were reinforced by a hands-on activity in which students used software to choose the geometry of an airfoil, which was then cut and tested to measure its lifting force.

Summer 2009

The program culminated with a 10-day residential Summer Institute. Students first spent four days on our campus participating in a wide variety of engineering-related activities that required team-building and hands-on inquiry activities to develop critical thinking and problem-solving skills and encourage engineering creativity. Students were also taken on a guided tour of the New England Air Museum (Figure 5) as well as the Connecticut Center for Advanced

Technology, where they participated in a 3-D simulation workshop. An *Apollo 13* movie night and planetarium show/observatory viewing were included in the scheduled evening activities, along with some unstructured but supervised time for the students to explore and familiarize themselves with the University campus recreational offerings, including the athletic facilities and student center. Our hope is that this experience would instill more confidence in any students who might feel apprehensive about living on a college campus.

A third faculty-developed workshop was another important element of the on-campus summer program activities. Building on their prior rocket-design challenge, students were this time tasked with designing, assembling and launching a low-thrust solid propellant rocket. Altitude was measured and compared with predicted values and prizes were awarded to the best designs.

The launch competition was scheduled for that Saturday afternoon, immediately after a family brunch at which the Dean of our School of Engineering and Technology spoke to parents about our university and its program offerings. Admissions staff was also present to provide parents with an overview of the college admission process, academic requirements and campus life. Parents were also provided with an overview of the itinerary for the upcoming five-day trip to NASA/Goddard Space Flight Center (GSFC) and then invited to stay for the launch competition.

The next morning, the GFA students, along with participating faculty members and undergraduate assistants, traveled to GSFC in Greenbelt, MD, for a four-day visit where they learned about state-of-the-art aerospace



Figure 5. GFA students at the New England Air Museum.



Figure 6. GFA student with NASA Scientist Aprille Ericsson.



Figure 7. GFA students at the University of Maryland's neutral buoyancy lab.

technology firsthand from NASA scientists and engineers (Figure 6). Program highlights included a visit to the nearby neutral buoyancy lab at the University of Maryland, Baltimore County (Figure 7), as well as a guided tour through several of NASA’s testing facilities. Students were also taken to the Smithsonian Institution's National Air and Space Museum in Washington, D.C. For the final day of the program, students returned to our campus for a closing event at which they received certificates of recognition for having completed the year-long program along with scientific calculators to better prepare them for their future studies. (Note that parental photo permission was obtained for all featured GFA students.)

Program Assessment and Dissemination

A growing body of literature suggests that students’ attitudes toward science, research skills, confidence in their ability to become scientists and engineers, and retention in these fields can be positively impacted by early exposure to and engagement with scientists and engineers working in the field. To evaluate the immediate and longer term impact of the GFA program activities on students’ awareness of and interest in STEM-related fields, as well as their perceived preparedness to pursue STEM-related careers, research is being conducted using the National Science Foundation-funded AWE pre-college outreach surveys, “Pre- and Post-Activity Survey for High School-Aged Participants – Engineering.”²³ These pre- and post-activity questionnaires are self-report instruments designed to measure the degree to which specific activities aimed at increasing interest in STEM-related careers have achieved their stated objectives.

Pre- and immediate post-program data was collected from 20 participants immediately before and after the 2009 Summer Institute. Permission was obtained from our University’s Institutional Review Board and students’ identities were kept anonymous by use of individual identification numbers kept separately from the survey instruments. All questions were optional.

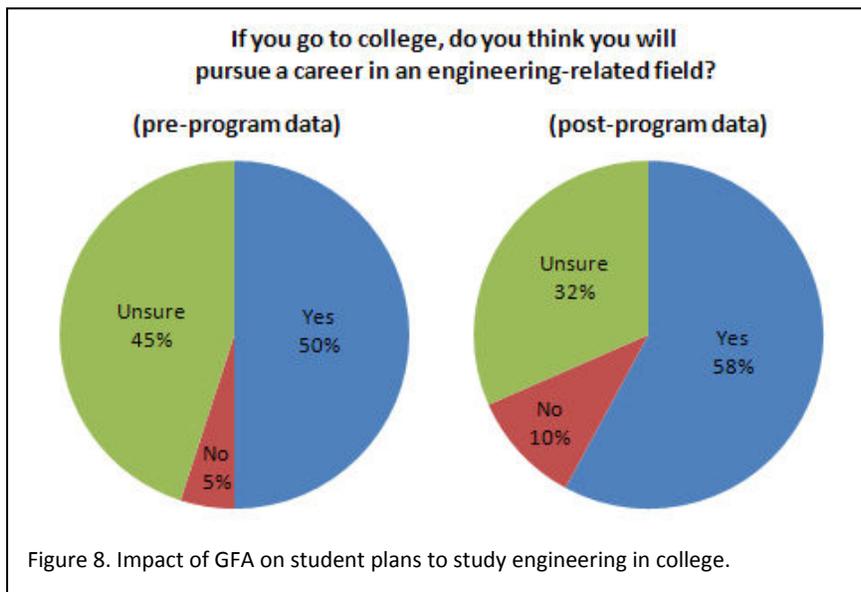
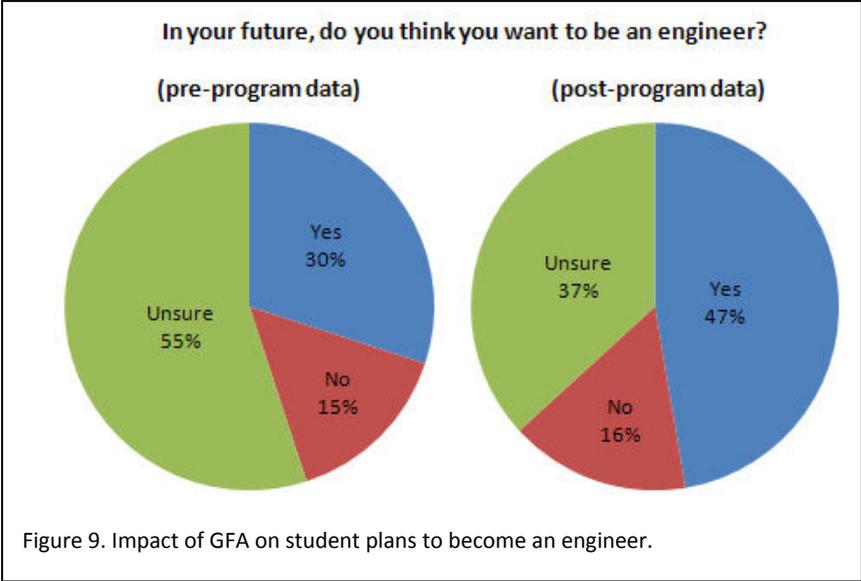
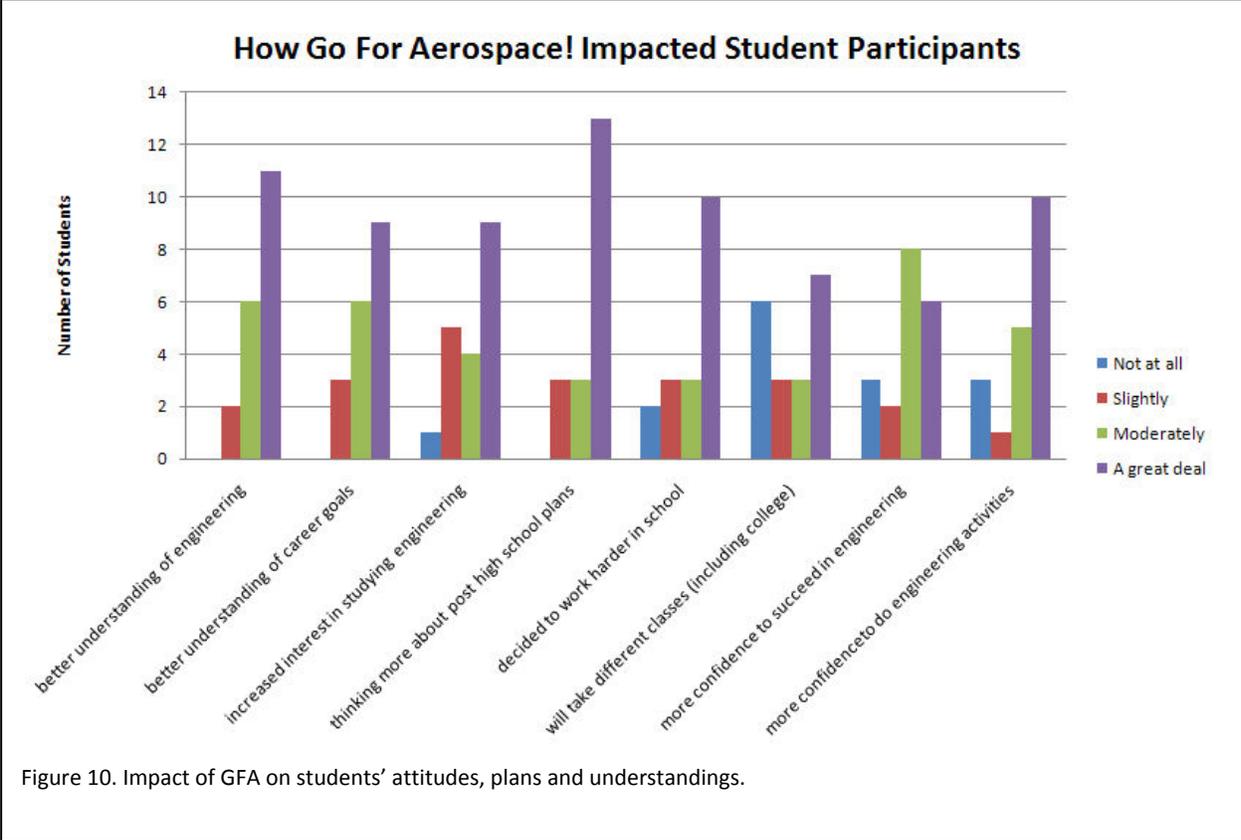


Figure 8 shows students’ responses to the question “If you go to college, do you think you will pursue a career in an engineering-related field?” both before and after the Summer Institute. Figure 9 shows their responses to the related question, “In your future, do you think you want to be an engineer?” For both questions, the number of students responding “Yes” increased.



In the post-program survey, students were also asked the question “How much did participating in this program impact each of the following?” for eight different items related to students’ attitudes, plans and understandings. In each category, more than half of all students reported that the program had impacted them either moderately or a great deal (see Figure 10).



In addition, students were asked to respond to the question “What do engineers do?” and their responses are shown in Figures 11a and 11b. Although many of their answers were unchanged, it is interesting to note that after participating in the program, all students disagreed with the statement that what engineers do “has nothing to do with me,” whereas before the program one student disagreed and another was unsure.

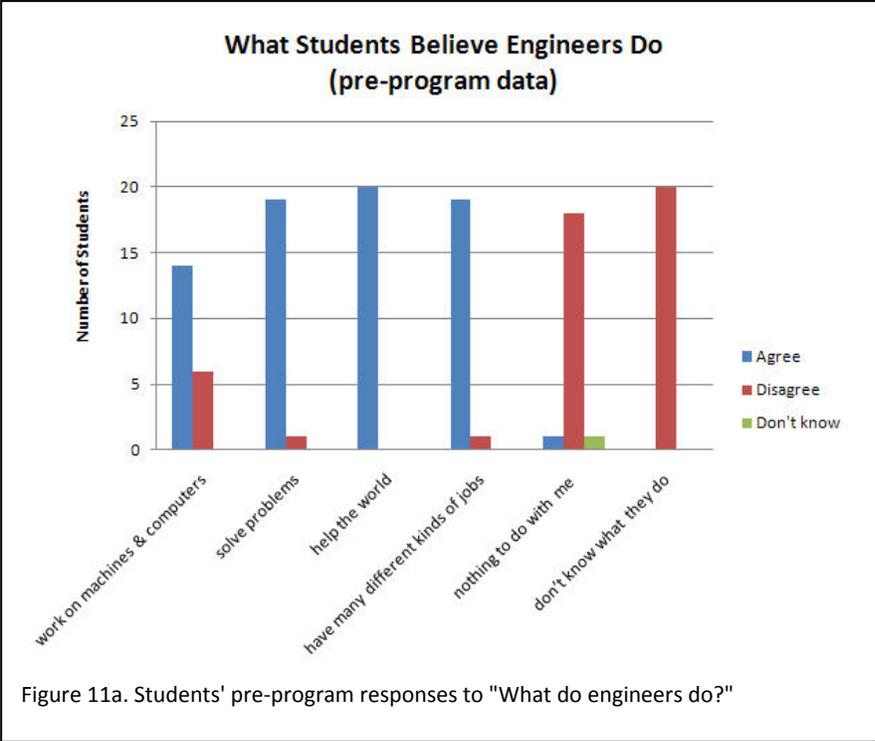


Figure 11a. Students' pre-program responses to "What do engineers do?"

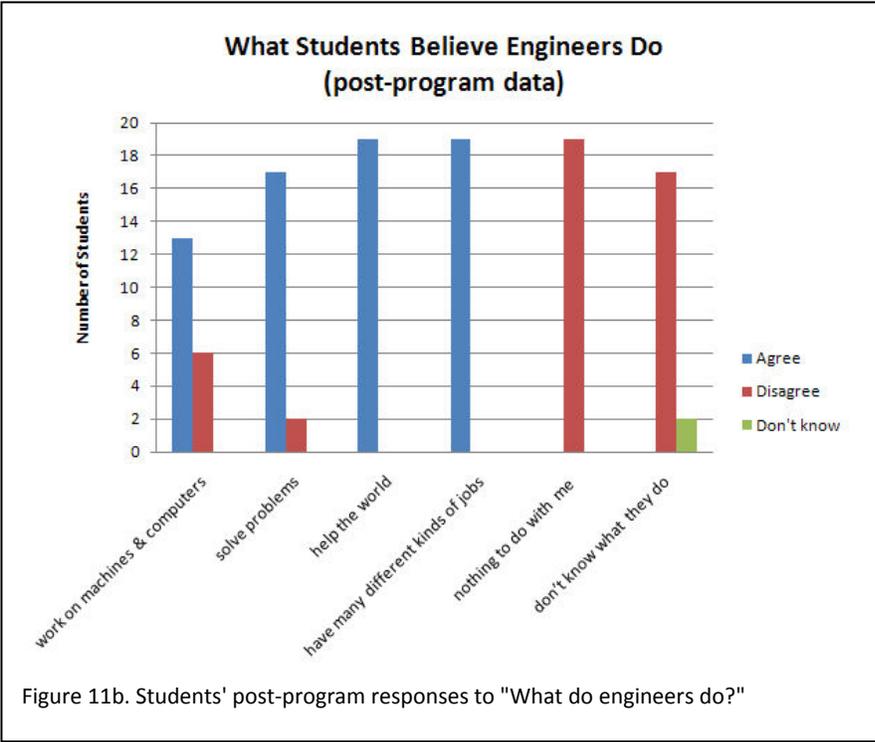
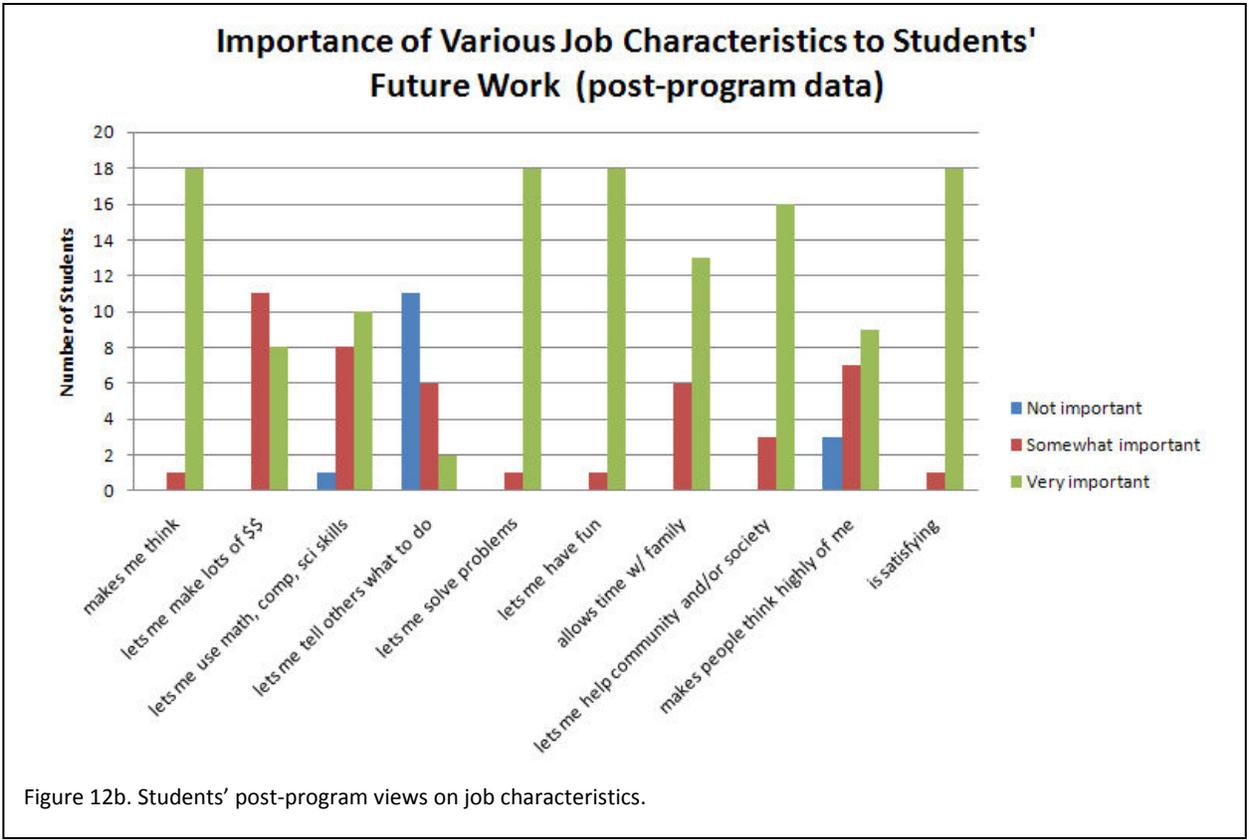
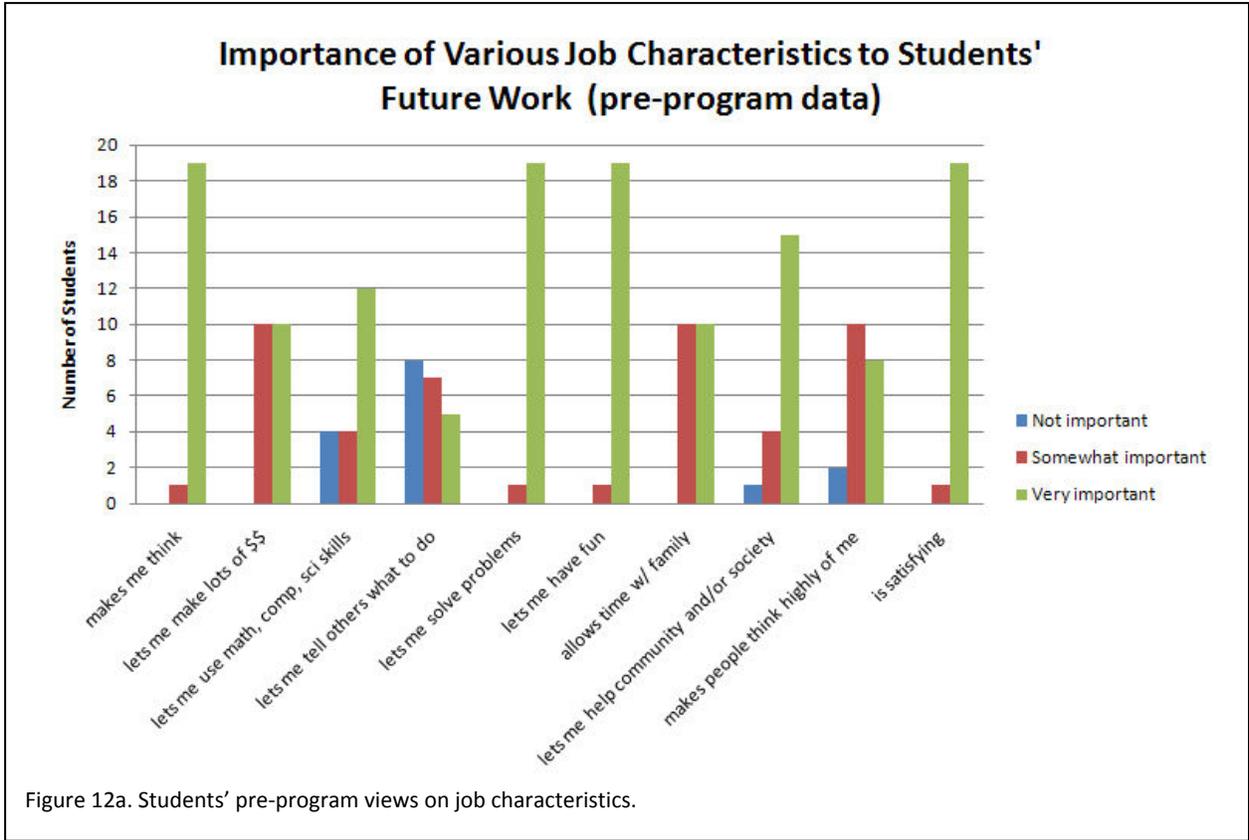


Figure 11b. Students' post-program responses to "What do engineers do?"

The AWE pre- and post-program surveys also examine the value students place on various job characteristics. Again, many responses were consistent between the pre- and post-program data (Figures 12a and 12b), however a few differences were observed. After participating in the



program, the one student who had not felt that work which allows for helping the community and/or society was important had changed his or her response. Also, prior to the program, four students indicated that using their math, computer and science skills was not an important job characteristic; after participating in GFA, only one student still felt this way. Fewer students also placed a high level of importance on being able to tell others what to do as part of their work after participating in the program. This may be an indication that our activities aimed at team-building met with some success.

Listed below are several students' responses to the post-program survey question, "What did you like best about this program?"

- "I liked the fact that we got to learn more about the different fields of engineering and were allowed to ask questions in order to clarify the disadvantages and advantages of careers in the engineering fields."
- "I really liked the planetarium and looking through the telescope."
- "I loved being exposed to the whole Aerospace industry and seeing all of the different types of jobs involved with it. In addition, I enjoyed meeting kids from other schools who had similar interests to me."
- "I loved the tour of the NASA facility with the Hubble telescope, the Smithsonian visit, and seeing different jobs available to engineers."
- "As a whole, meeting other people, and learning scientific concepts. Specifically, the trip to the planetarium where we learned about inspiration, physics, and astronomy."
- "I liked visiting sites related to aerospace. I learned and saw much of what engineers do."

Students were also asked, "If you were in charge, how would you change this activity?" and the most overwhelmingly popular suggestion was for the program coordinators to increase the number of hands-on activities.

Along with these comments and other information including gender, ethnicity, and current course enrollment, the AWE surveys also record students' post high school plans. Before the program, one student had indicated that he or she was planning to "Attend a technical school (for example: business school, beauty school, technology school, etc)." After the program, this answer had changed to "Go to a college or university," which is how all other students had responded on both the pre- and post-surveys. A third version of the AWE survey will be administered in February 2009 and information regarding the college choices of participating students will also be collected at that time.

Limitations

Although the initial results are promising, our research was not without limitations such as the small sample size of 20 students. Our current cohort is larger (45) but the numbers are still modest. In addition, due to the time required to seek and receive Institutional Review Board approval, the pre-program surveys were not administered at the onset of the entire program but rather at the beginning of the Summer Institute. As a result, we were unable to record any impact that might have resulted from the events that occurred during the previous fall and spring semesters. In future years of the program, students will complete the pre-program surveys at the fall kick-off event (the 2009-2010 cohort has already done so). In spite of these limitations, we

feel that our results will none the less be of interest to members of the community wishing to implement similar programs at their institutions.

Conclusions and Future Directions

Overall, we feel that the pilot year of the GFA Program was successful. However, based on student feedback as well as our own observations, there are several modifications being made. For instance, we are planning to incorporate more hands-on activities, especially during the Summer Institute, and to allow more time to familiarize students with the equipment available in the University labs. While visiting GSFC last August, we were also introduced to additional educational resources and opportunities made available through NASA, including the Digital Learning Network (DLN), which allows for real-time teleconferencing with NASA personnel, and the Interdisciplinary National Science Project Incorporating Research and Education Experience (INSPIRE) program. In future years of GFA, we plan to utilize these resources to more effectively integrate our spring and summer programs and to better prepare our student participants for their experiences at GSFC and beyond.

We also plan to invite GFA “alumni” from previous years to selected program events. Several students from last year’s program have already attended this past fall’s kick-off dinner where they shared their experience with students from the current cohort. Through these efforts, as well as a web presence that is currently under development, we hope to build a community that can serve as a gateway to learning about aerospace engineering and careers for students, teachers, and parents.

The results of our research will also be important in identifying potential strategies for similar outreach programs and will thereby impact the STEM education field in general. Through a follow-up, multi-year study, we will be able to assess the overall effectiveness of our approach and make continual improvements to the program. Ultimately, it is hoped that information derived from this project will demonstrate how the GFA program can be adapted by other organizations and to other STEM disciplines, thus further growing and developing the STEM talent pipeline.

Acknowledgments

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