Go For Aerospace!: Recruiting the Next Generation of Engineers

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Abstract

For our nation to maintain its competitive edge in the global economy, the pipeline of interested and qualified students prepared to enter science, technology, engineering and math (STEM) careers must be increased. To help address this problem, Central Connecticut State University received funding from NASA to conduct an innovative, extracurricular program, "Go For Aerospace!" (GFA). Currently entering its third year, GFA reaches out to high school juniors, especially those from underrepresented groups, with high potential in math and science and fosters their interest in engineering and related fields. Students from four urban school districts throughout the state are nominated for the program by their math and science teachers, and approximately 25 high-achieving juniors are selected to participate each year.

The year-long program begins in the fall with a kick-off event for students and parents. In the spring, students work with university faculty and students on engineering projects and visit industrial aerospace facilities to tour labs and speak with practicing engineers. The program culminates with a 10-day residential Summer Institute. Students spend four days on campus participating in varied activities, including a rocket design competition and 3-D simulation workshop; they next travel to NASA's Goddard Space Flight Center for a four-day visit where they learn about state-of-the-art technology firsthand from NASA scientists and engineers.

To evaluate the immediate and longer term impact of GFA, research is being conducted using the National Science Foundation-funded AWE pre-college outreach surveys. These pre- and post-activity questionnaires are designed to measure the degree to which specific activities aimed at increasing interest in STEM-related careers have achieved their stated objectives. Data is also being collected on the future college choices of participating students. 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.

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 [1]. Recent occupational projections from the Bureau of Labor Statistics [2] 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% [3]. 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 [4].

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 [2]. 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 [5].

Equally alarming, international comparisons of student mathematics and science performance indicate that U.S. students scored below average among industrialized countries [6]. 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 [7]. 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 [3].

Demographic Disparities in Math and Science Achievement

According to the National Science Board's *Science and Engineering Indicators 2008* [6], 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 [6]. 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 [8].

The outlook is also bleak in higher education. Nationwide statistics [9] 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" [6]. 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 [10]. 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 [11-15].

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 [16].

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 engineering [17] 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 [18], a condition worsened by the known outflow of engineering graduates from the state [19]. According to regional graduate retention data [19], 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.

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 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.

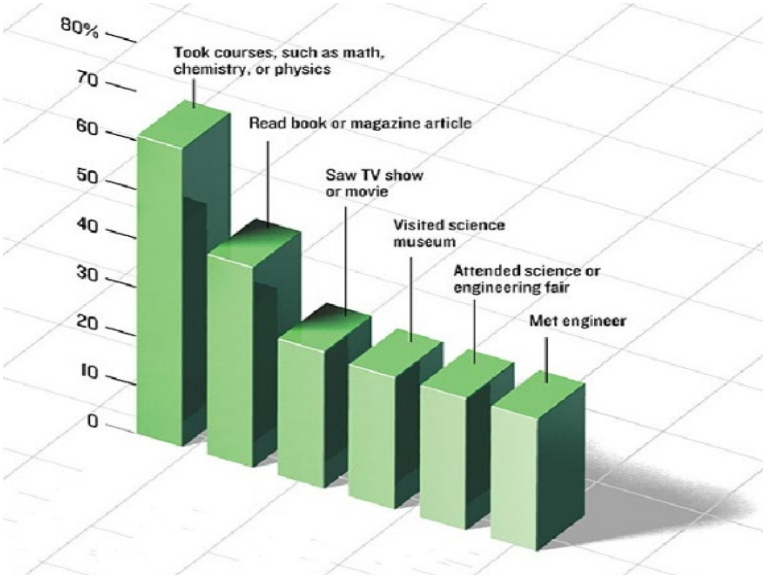

Figure 1. Activities that inspired survey respondents to consider being an engineer/technology professional [23]. *(Source: The Response Center, a market research firm in Fort Washington, Pa., conducted the survey for IEEE Spectrum and IEEE-USA. An e-mail questionnaire was sent to about 2000 higher-grade 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.)*

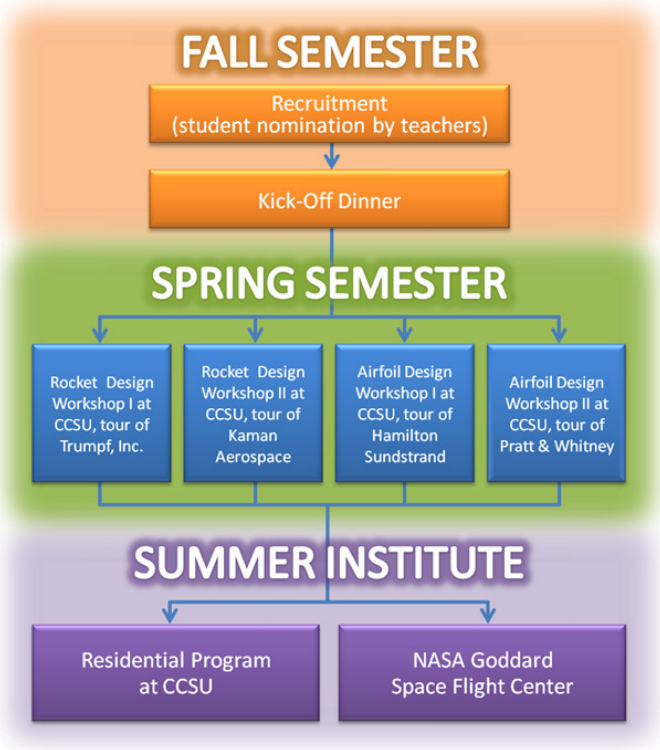

Figure 2. Go For Aerospace! at a glance.

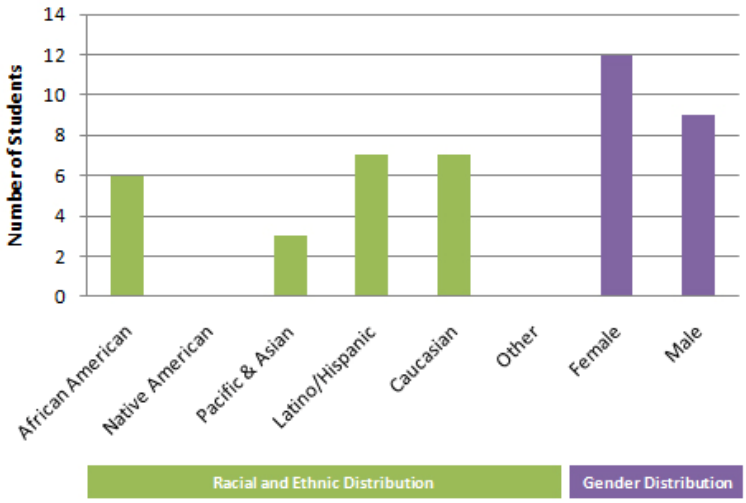

Figure 3. Race/ethnicity and gender distribution of 2008-2009 Go For Aerospace! participants.

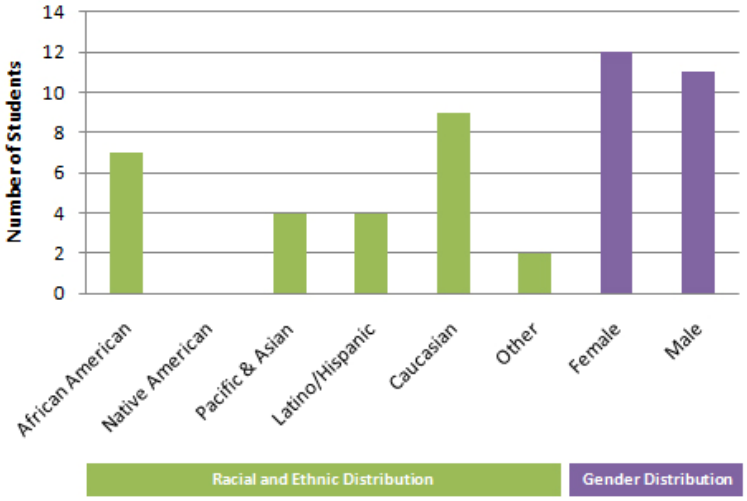

Figure 4. Race/ethnicity and gender distribution of 2009-2010 Go For Aerospace! participants.

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 [20]. 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.

An overview of the year-long GFA program is provided in Figure 1 and each of its three main components are described below. We are currently in our third year of the program.

Fall

Recruitment is conducted in early fall of each year of the program. The student selection process is an important part of the project and is accomplished through nomination by math and science teachers in four urban school districts throughout the state. This allows for identification and mentoring of talented students, especially among underrepresented groups, who might otherwise not pursue a degree in engineering and perhaps not even consider a college education at all.

Based on their recommendations, more than 40 high-achieving high school juniors have been selected over the first two years of the program (demographic data provided in Figures 3 and 4) and the current cohort consists of 45 students (demographic data compilation still in progress). Each year, a kick-off dinner has been held on our campus with keynote speakers including a Coast Guard Aviator and NASA Astronaut as well as an aerospace engineer who designed equipment for multiple NASA missions and a woman who is one of seven teachers nation-wide selected as the first astronaut-teachers to participate in the nonprofit Teachers in Space program. 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 [21]. This underscores the importance of parent involvement.

Spring

During the spring, students participate in four sessions, the aim of which is to provide 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 month between February and May, students have been transported from their respective high schools to our campus, where they spend the morning working with university faculty and students on projects related to mechanical and aerospace engineering. After lunch on campus, the students visit industrial aerospace facilities to tour research and manufacturing labs and speak with practicing engineers. Each month the students visit a different company.

Figure 5. Undergraduate assistant helps GFA student prepare her rocket for the launch competition.

Figure 6. Undergraduate assistant helps GFA students test their airfoil designs.

Two workshops were developed specifically for the on-campus (morning) component of these spring sessions. Each is divided into two sessions so that the first workshop takes place over the first two visits and the second occurs during the latter half of the semester (see Figure 1, "Go For Aerospace! at a glance"). All workshops begin with a brief lecture introducing students to the relevant theory and its applications.

1) Rocket Design and Building Workshops I and II
   Teams of two students calculate the performance (thrust, altitude and flight time) and main geometrical parameters of a rocket using NASA's Rocket Modeler software. They next use these parameters to design and build water bottle rockets from 2-liter soda bottles. The final event of this workshop is a launch competition (Figure 5) in which altitude is measured and compared with the calculated (theoretical) altitudes. Student teams receive awards for the highest altitude and best correlation between experimental results and theoretical predictions.
2) Airfoil Design and Testing Workshops I and II
   The objective of this workshop is 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 learn which wing and airfoil designs provide high lift and low drag. The main parts of airplanes and their functions are also introduced. These theoretical concepts are reinforced by a hands-on activity in which students use software to choose the geometry of an airfoil, which is then cut and tested to measure its lifting force (Figure 6).

Figure 7. GFA students at the New England Air

Summer

The program culminates with a 10-day residential Summer Institute. Students first spend four days on our campus participating in a wide variety of engineering-related activities that require team-building and hands-on inquiry to develop critical thinking and problem-solving skills and encourage engineering creativity. These include materials testing and wind tunnel experiments, as well as rides on our student-designed and built "Moon Buggy." Students are also taken on a guided tour of the New England Air Museum (Figure 7) as well as the Connecticut Center for Advanced Technology, where they participate in a 3-D simulation workshop. An *Apollo 13* movie night and planetarium show/observatory viewing are 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.

Figure 8. GFA student with NASA Scientist Aprille Ericsson.

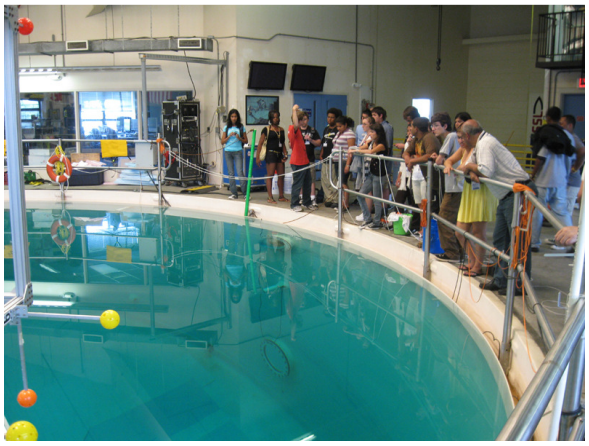

Figure 9. GFA students at the University of Maryland's neutral buoyancy lab.

Our hope is that this experience will instill more confidence in any students who might feel apprehensive about living on a college campus.

A third faculty-developed workshop is another important element of the on-campus summer program activities. Building on their prior rocket-design challenge, students are this time tasked with designing, assembling and launching a low-thrust solid propellant rocket. As with the first launch competition, altitude is measured and compared with predicted values and prizes are awarded to the best designs. The event is scheduled for a Saturday afternoon, immediately following a family brunch at which parents are 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, travel to Goddard Space Flight Center in Greenbelt, MD, for a four-day visit where they learn about state-of-the-art aerospace technology firsthand from NASA scientists and engineers (Figure 8). Program highlights include a visit to the nearby neutral buoyancy lab at the University of Maryland, Baltimore County (Figure 9), as well as a guided tour through several of NASA's testing facilities. Students are also taken to the Smithsonian Institution's National Air and Space Museum in Washington, D.C.

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 "[22]. 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 participants before and after the 2008-2009 and 2009-2010 programs. 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.

Figures 10 and 11 show 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 2008-2009 and 2009-2010 programs, respectively. Figures 12 and 13 show 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, with even greater gains realized in the second year of the program.

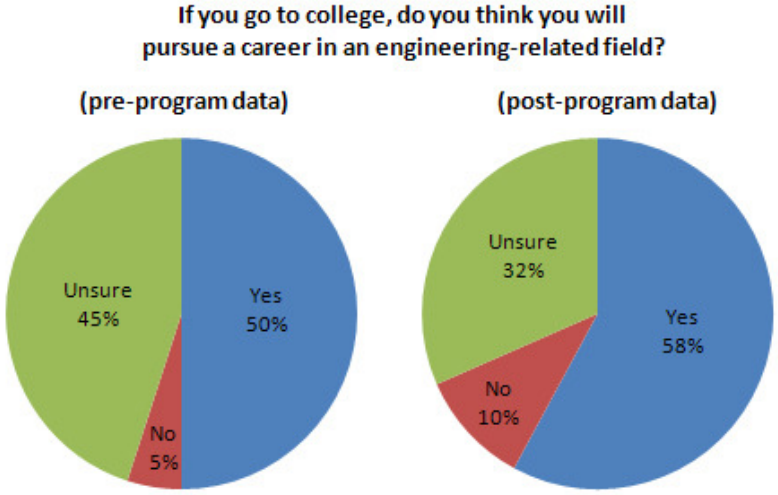

Figure 10. Impact of GFA on student plans to study engineering in college (2008-2009 data, n=20).

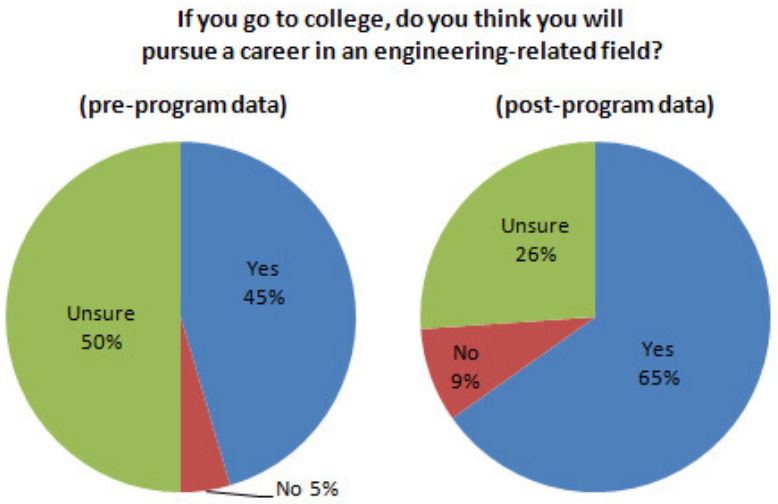

Figure 11. Impact of GFA on student plans to study engineering in college (2009-2010 data, n=23).

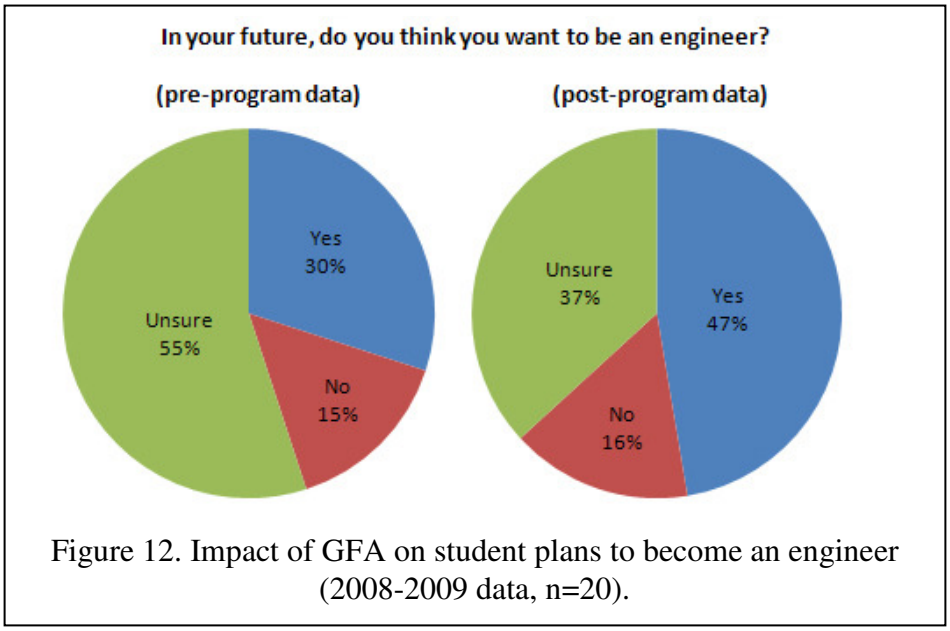

Figure 12. Impact of GFA on student plans to become an engineer (2008-2009 data, n=20).

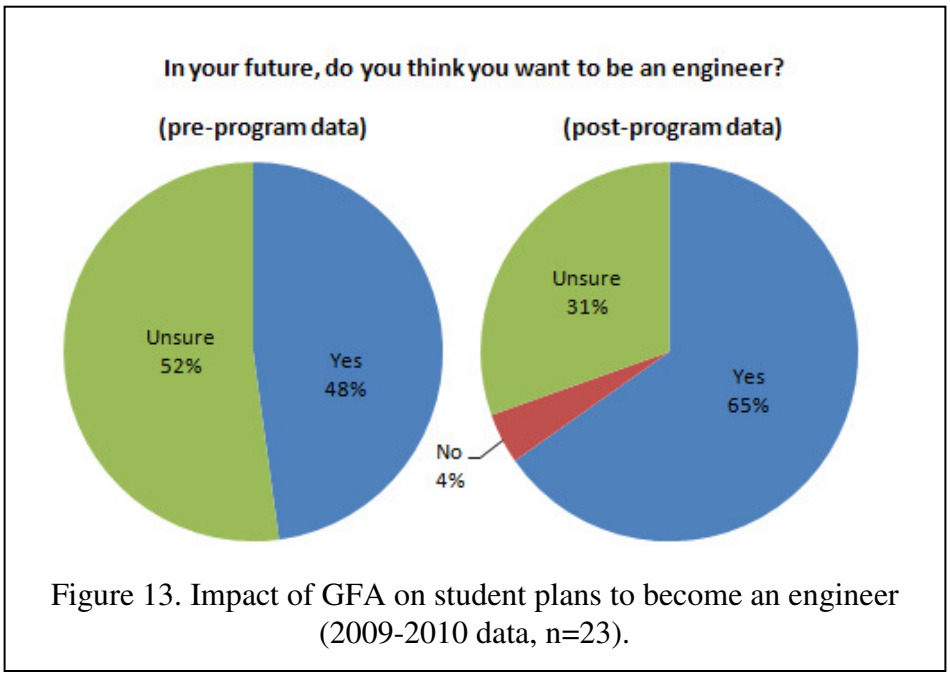

Figure 13. Impact of GFA on student plans to become an engineer (2009-2010 data, n=23).

In the immediate 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 in both cohorts reported that the program had impacted them either moderately or a great deal (see Figures 14 and 15).

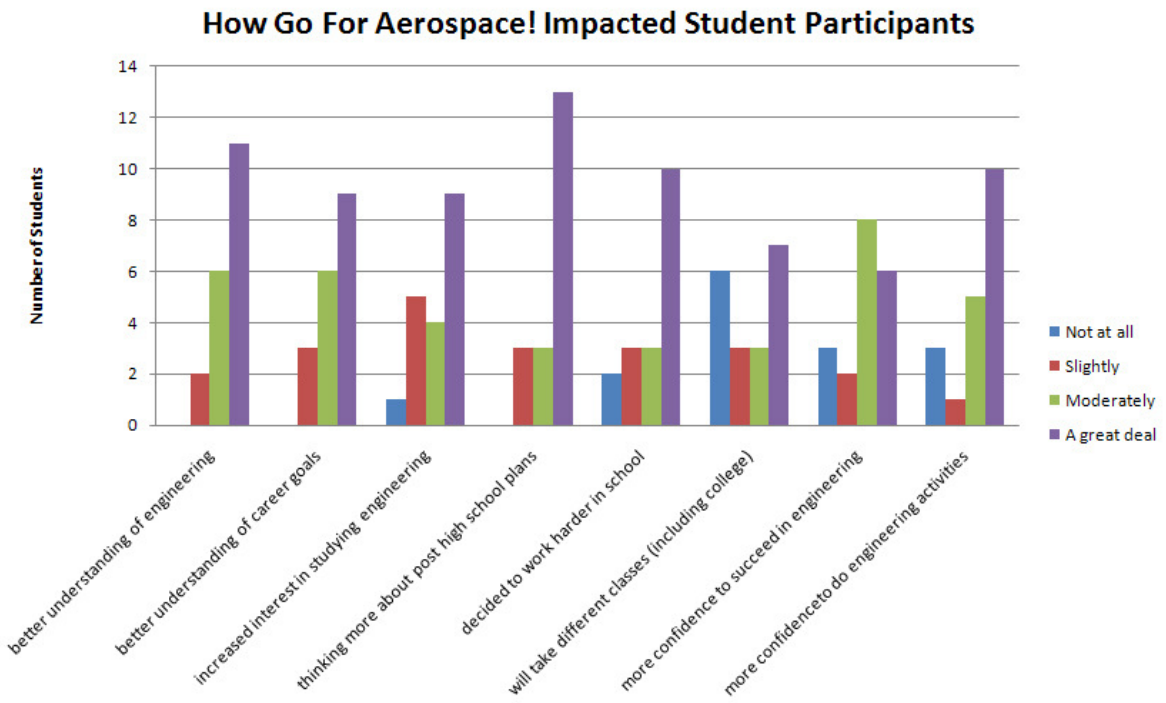

Figure 14. Impact of GFA on students' attitudes, plans and understandings (2008-2009 data, n=20).

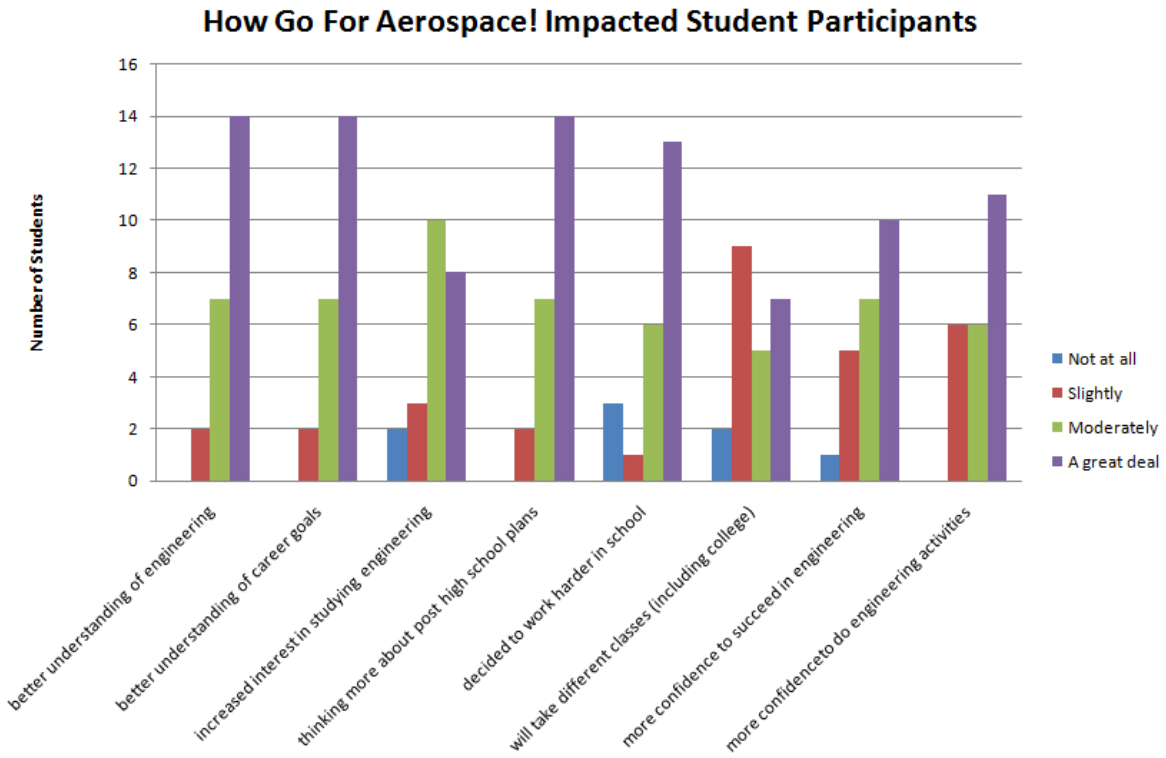

Figure 15. Impact of GFA on students' attitudes, plans and understandings (2009-2010 data, n=23).

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 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."
- "Meeting new people and learning about all the engineering possibilities."
- "I got to meet different kids and learned about engineering."
- "I liked being exposed to careers, people, and ideas that were previously unknown to me."
- "Meeting other students from other schools and learning about career opportunities."
- "I liked the fact that everyone looked out for one another or when needed help and I felt that I learned a lot."
- "All the tours we went on because I was able to inspire my future there; and maybe work there. Also the speakers had great topics that we wanted to learn more! Plus all of the places we went to the entire program were super cool."

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

Along with the pre- and immediate post-surveys, the AWE set of instruments also includes a long-term follow-up version which can be used to record, among other information, students' post high school plans. As this data is directly related to our goals, it is of critical importance to us. As such, a third, follow-up version of the AWE survey was sent to the 2008-2009 cohort by mail in February 2009 in hopes of determining which colleges and degree programs our past participants had selected. Disappointingly, no responses were received despite multiple mailings. We next sent out a SurveyMonkey™ version of the same survey via email and through a Facebook™ group which had been created for that GFA cohort, however this, too, yielded a very poor response rate (n=2). Ultimately, a much shorter, four-question survey was created using Google™ Docs and distributed via Facebook. This yielded the most successful response rate (n=10) and our results are summarized in Table 1. As the data demonstrates, our program was influential in four of the 10 respondents' decisions to pursue a STEM major in college.

Table 1. Long-term follow-up survey results (2008-2009 data).

Currently you are...	If you are attending a university, which university are you attending?	What is your major?	Did participating in the program influence your decision in picking a school or major?
Attending a university	Boston University	Chemistry	Yes
Attending a university	University of Connecticut	Electrical Engineering	Yes
Attending a university	Rensselaer Polytechnic Institute	Information Technology and Web Science	No
Attending a university	Saint Joseph College	Biology/Pre-Pharmacy	No
Attending a university	University of Connecticut	Molecular & Cell Biology	No
Work and college	Naugatuck Valley Community College	Chemistry	Yes
Attending a university	Boston College	Biology	No
Attending a university	Stevens Institute Of Technology	Electrical Engineering	I already knew what I wanted to major in and why. The program helped broaden my knowledge on engineering as whole.
Attending a university	University of Connecticut	Biological Sciences/Allied Health	No
Attending a university	Boston University	Mathematics	Yes, it made me like math.

Limitations

Although the initial results are promising, our research was not without limitations such as the small sample size of approximately 20 students per year for each of the first two years. While our current cohort is larger (45), the numbers are still somewhat modest. In addition, we had not anticipated the level of difficulty that we encountered in collecting survey information from past participants after they leave the program. In the future, we plan to continue to pursue the use of social networking software as a means of collecting follow-up survey data since, not surprisingly, this appears to be the most likely way to reach our target audience. 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 GFA Program has been successful. However, based on student feedback as well as our own observations, we have made several modifications along the way. For instance, we have added more hands-on activities, especially during the Summer Institute, and allotted more time to familiarize students with the equipment available in our University labs. We have also interchanged the two spring workshops so that the rocket launch, which must be conducted outdoors, will take place during the warmer months.

Our data collection is ongoing and we plan to continue to disseminate our results. 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. 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. 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

The authors would like to thank Captain Daniel C. Burbank, Ms. Rachael Manzer and Mr. Donald W. Rethke; undergraduate student assistants Dennis Akin, Justin Amenta, Ryan Garvin, Margarita Gudzon, Jonathan Kentfield, Ewelina Malejczyk, Jessica Meissen, Diana Nagler, Kevin Schindewolf and Jason Williams; Hamilton Sundstrand; Kaman Aerospace; Pratt and Whitney; Sikorsky Aircraft and Trumpf Inc. for their generous support of this project. The material is based upon work supported by NASA under grant numbers NNX08AP06G and NNX09AQ24G.

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