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Brief Report

High School Is Not Too Late: Developing Girls' Interest and Engagement in Engineering Careers

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Although experts increasingly call for science, technology, engineering, and math (STEM) education to begin in middle and elementary schools, a 3-year intervention beginning with high-achieving female high school sophomores demonstrated that young women can develop a serious interest in engineering in high school. However, subsequent post-high school study of the participants showed that interest in engineering was not enough for lower-income minority women to pursue engineering in college. It should be noted that their decision against pursuing engineering in college was not due to their lack of academic preparation or interest in the field, but to a lack of financial resources and social support for engineering, as well as fears of failure. Career counselors and college recruiters have an important role to play in the recruitment and retention of girls of color in engineering and other STEM college majors, including facilitating support and access to appropriate programs and resources at pivotal times.

Keywords: STEM career counseling, minority girls, and engineering

There can be little doubt that science education in the United States is not tapping the potential of the many diverse groups who populate the country (Ferrini-Mundy, 2013). Decades of research, funding, and effort have done little to budge the persistently low numbers of African Americans, Hispanics, and Native Americans—as well as White women in fields such as physics, computer science, and engineering—in science, technology, engineering, and math (STEM) degree programs and jobs (National Science Board, 2012). The need to broaden participation and diversity in STEM careers is critical.

Guidance counselors, advisors, teacher/mentors, and others interested in career counseling and development in STEM have sought strategies

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for more effective recruitment and retention of women and people of color in these fields (Gott, Harris, Hoster, McFee, & Pollock, 2013; Stewart, Russell, & Wright, 1997; Traurig & Feller, 2008). However, such efforts seldom address the important question of why so few African Americans, Hispanics, Native Americans, and, in some fields, women, enter college STEM programs in the first place. Recent reports have called for increased attention to STEM in K–12 education (American Association of University Women, 2010; National Research Council, 2011) but do not make broadening access and participation the central issue. Increasingly, attention has focused on improved elementary and middle school education on the grounds that high school is too late to develop an interest in STEM.

Here we report the results of a 3-year intervention program developed to spark and sustain predominantly low-income, Hispanic, and African American high school girls' interests (defined as expressions of curiosity, desire to learn, enjoyment and engagement in activities related to an area of study and employment) in engineering careers. The intervention was part of a 7-year longitudinal study that followed the young women as they graduated from high school and moved on to college. We found that although the participants began high school with little or no knowledge of engineering, it was easy to develop their interest, which led them to seriously consider engineering as a college major and future career. Results indicated, however, that interest was not enough. It was difficult, especially for those from low-income minority groups, to actually pursue engineering as a major in college.

Participants, Intervention, and Procedures

The Female Recruits Explore Engineering (FREE) and Pathways Project was initially an after-school intervention and research study that began with 131 high-achieving young women who participated in guided explorations of engineering in 10th grade, self-initiated engineering projects in 11th grade, and college mentoring in 12th grade. Subsequently, their post-high school trajectories (pathways) were tracked for 4 years. The girls invited to participate had strong academic records in math and science through ninth grade. They were recruited with the help of guidance counselors and teachers in 10 participating schools. All who volunteered to participate were included in the project.

Participants came from diverse demographic backgrounds and communities in three states: Colorado, Iowa, and Ohio. Of the young women who were active in the study throughout 3 years of high school, 36% were Latina, 33% were White, 12% were Black, 7% were Asian, 7% were multiracial, and 4% were Native American. (Percentages do not total 100 because of rounding.) Two thirds were from lower-income families, and two thirds would be first-generation college students.

Participant observation and informal interviewing were used to document what happened during the first 3 years of intervention activities. During the project's 1st year, the girls explored engineering through websites, career fairs, interactions with practicing engineers, and visits to engineering workplaces and colleges. In the 2nd year, participants conducted their own hands-on group engineering projects with the assistance of the FREE staff and "mentor" engineers. During

their senior high school year, the participants' interests and inquiries centered on researching colleges, finding funding for college, and applying to colleges. A secure wiki-type website was created for the girls to share their explorations and to complete surveys about their previous experiences with engineering and technologies, their school performance, their future plans, and their social networks. Each girl was given a BlackBerry smartphone to communicate with other FREE participants, capture "in-the-moment" thinking, and complete the research tasks associated with the project. With the girls' and their parents' permission, these data were recorded and archived for analysis. Regular meetings, field trips, group projects, and ongoing communication via the wiki and smartphones among the girls and with the project staff were intended to foster a sense of community among the participants, providing encouragement and support for the young women to go to college and consider engineering.

Post high school graduation, Facebook's private group feature was used to stay in regular contact with the girls and collect survey responses about their experiences in college and work. On Facebook, questions were provided weekly by the researchers, and responses were posted and read by participants. In addition, Facebook personal site postings and messages were captured for analysis, and face-to-face interviews were conducted twice each year to track the participants' trajectories for 4 years after they graduated from high school. The data collection concluded in the summer of the participants' 4th year after high school graduation.

Data Analysis

All of the qualitative data were analyzed using a coding scheme developed from the initial research questions (a priori codes; e.g., manifestations of interest in engineering, constructions of engineering as gendered, position-taking with regard to engineering), and a review by all of the researchers of the accumulated data from each of the three states (in situ codes; e.g., fit with girls' lives, future plans, confidence in academic abilities). The coding scheme was applied to the data using ATLAS.ti qualitative data analysis software. These coded categories also were sorted into 2-month segments to capture change over time and were aggregated by demographic characteristics.

Results

Although all the girls in the project were taking college preparatory courses and doing well in advanced science and math, they reported knowing little about engineering at the outset of the project. Only 18% (24 of 131) of the girls who began FREE as high school sophomores were even remotely considering engineering for possible careers at the time the program began. The vast majority (82%) reported that they knew little or nothing about engineering, had never met an engineer, had no idea what an engineer does, and had never considered it as a field of study or career possibility for themselves. However, by the end of the 2nd project year (August 2008), more than half of continuing participants (43 of 75 continuing, or 57%) were seriously considering a career in an engineering field. One participant described her changed attitude this way:

> When I first heard the word engineer, I was not exactly sure what they did. I now understand that engineers work in almost every part of anything that has to be made; this is really exciting because it means that as an aspiring engineer there will be countless opportunities.

After exploring engineering in monthly FREE meetings, attending career fairs, meeting practicing engineers, and visiting engineering schools and workplaces, the participants came to realize that engineering was all around them; thus, they started to think about how it was manifested in their everyday lives and they were eager to learn more. One participant wrote,

> It's very interesting that there are so many different parts within engineering. I never knew about all the things that engineers do that impact our daily lives. I would like to learn more about the environmental part of engineering because I think that it is neat how engineers deal with everything around us like the water we drink and the roads we drive on.

The young women further extended their interest in and knowledge of engineering through small-scale engineering projects they identified and carried out with the help of engineer mentors in the 2nd year of the program. Planning and executing these projects expanded their knowledge of engineering, gave them some familiarity with technical language, and heightened their interest in the social and entrepreneurial applications of engineering. Sixty-eight different projects were suggested by the participants, and 25 were pursued. Projects fell into three categories: (1) innovations (e.g., adjustable high-heeled shoes for women, a concept later named by *Time Magazine* as one of 100 best innovations of 2007; the FREE girls developed their idea before the *Time* announcement); (2) addressing a community or social need (e.g., designing a playground for disabled children); and (3) building an attractive, wearable product (e.g., clothing accented with light-emitting diode displays).

Consistent with the general principles of engineering design (design-build-test cycle), the FREE participants identified a need for the product and generated several product concepts. As part of their project, they searched for relevant technical knowledge and tried to put it to use; they considered both aesthetics and function; they constructed prototypes; and they communicated, collaborated, and problem-solved with each other to develop ideas and manage logistics. Ultimately, all but two groups produced either an actual product or a detailed storyboard. All of the projects were publicly presented, and professional engineers judged them equivalent to initial design projects of 1st-year college undergraduates in engineering.

During the course of FREE in high school, the girls' interests in engineering grew and developed. As seen in Figure 1, high school was not too late to get talented girls interested in engineering. To be sure, some participants dropped out of FREE because of a lack of interest and other reasons, such as moving away, competing activities, and meeting the needs of family members. However, in August 2008, when the young women began their senior year of high school, 75 (of 131 sophomores), or 57% of those who started in the FREE program, were interested enough to continue their involvement, and half of those 75

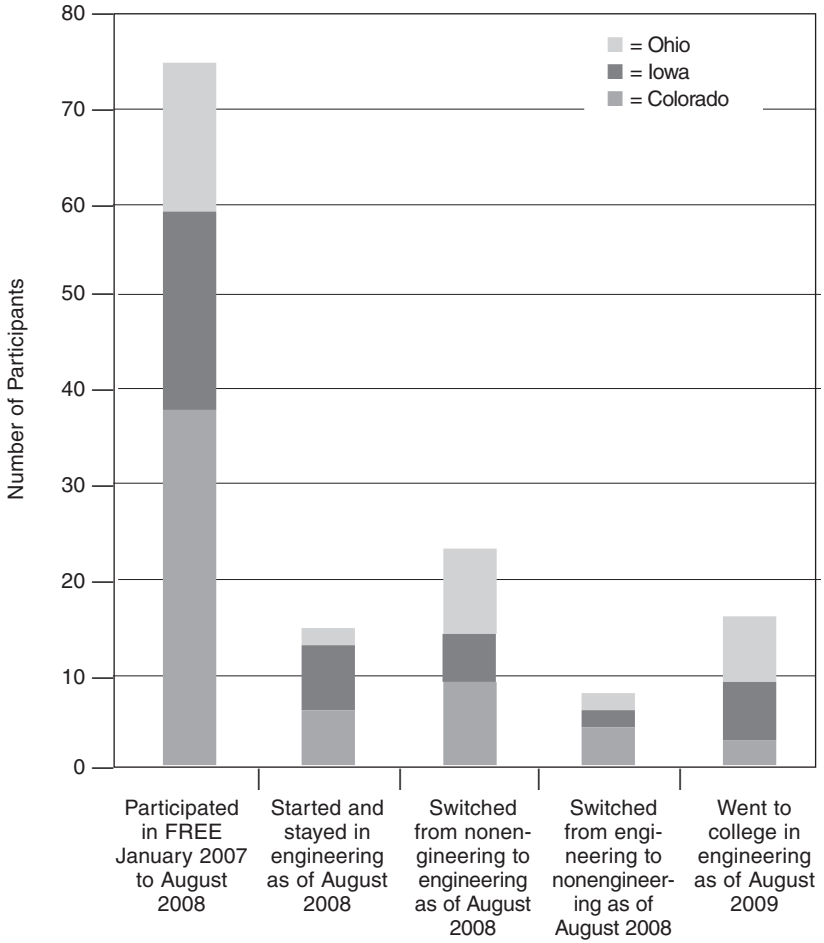

FIGURE 1

FREE Participants' Trajectories of Interest in Engineering From 2007 to 2009

reported that they were thinking seriously about pursuing engineering in college. Moreover, more participants shifted their interest toward engineering compared with those who shifted away. In other words, after 18 months in FREE, the percent of girls retained in the program was substantial (57%), and the percent who talked seriously about going on to pursue engineering was impressive (51%)—compared with the percent interested when the project began (18%). The percent of FREE girls who subsequently enrolled in engineering in college was much lower (21%) than the percent who considered it, with Colorado having the lowest percentage (and the highest percentage of low-income girls), Iowa in the middle, and Ohio with the highest (where the girls were higher income and more were White or Asian). In 2013, the National Science Foundation reported that women constitute 17% of all those entering college engineering, with Black, Hispanic,

and Native American women making up only 3% of the total. In this context, the fact that one fifth of FREE participants decided to pursue engineering in college is impressive, considering the largely minority and low-income population, the girls' limited entering knowledge of engineering, and the absence of engineering in most high schools.

Furthermore, a high proportion of the continuing FREE participants went on to study nonengineering STEM fields in college. Thirty-three percent of continuing FREE participants (n = 75) enrolled in such STEM disciplines as mathematics, computer science, biology, zoology, chemistry, and environmental science. After 4 years of college, nine of the 16 young women (56%) who went into college engineering graduated with an engineering degree (while 80% of those who went into nonengineering STEM disciplines graduated from college in those fields).

What happened to all the enthusiasm for and engagement with engineering? It is not the lack of interest that resulted in relatively few of the FREE participants entering college in engineering and even fewer graduating. All but a few of the young women who continued in FREE post high school reported that they were still very interested in engineering and grateful for the learning opportunity FREE provided. They all pointed to ways in which FREE had expanded their knowledge and increased their self-confidence in fields they never expected to enjoy. An Ohio participant stated,

> Although I didn't go into engineering, because of FREE I'm still interested in it. Whenever I see something in the news about a bridge or road collapsing, or some environmental problem, I think, "How would an engineer solve this problem?"

Many participants pursued their FREE engineering projects (from their junior year in high school) for several years afterward.

However, for most of the low-income and minority young women, a lack of financial resources kept them from going to a college with an engineering program, or, in some cases, to any college. Furthermore, many of the girls, despite doing well in high school in math and science, harbored self-doubts about being "good enough" to enter or stay in engineering. Those who would be the first in their family to attend college feared that engineering would be "too hard" for them in addition to all the other expectations for their college careers. Those dependent on scholarships worried that engineering courses would jeopardize the good grades needed to retain their scholarships. Several of the young women who dropped engineering for another major reported a lack of support from professors, peers, advisors, and others, and the feeling that they "did not belong" led them to major in programs that offered a more supportive academic climate.

Discussion

In recent years, many in the STEM education community have argued that intensive efforts to increase interest and proficiency in STEM—especially for girls, students of color, and low-income students—should start in middle or even elementary school; high school is said to be too late (American Association of University Women, 2010; Lubinski & Benbow, 2006). Although an early start is certainly commendable,

the FREE study suggests that we should not disregard opportunities that can be provided in high school or for high school-aged students. If more students, at all levels, can have rewarding experiences exploring engineering, many more are likely to become interested and want to pursue it.

As we learned, however, it is not enough to spark interest. Underrepresented students need substantial financial resources, as well as ongoing social and educational support, to make the transition from an interest in engineering to a college major and a career in an engineering field. At a pivotal time in the transition from high school to college, counselors and mentors can play a crucial role in guiding students to financial resources, such as targeted college scholarships. They can assist and encourage them to apply. They can also alert them to campus social and academic resources, such as minority engineering programs, the Society for Women Engineers, Engineers Without Borders, and scholarship advisors. Furthermore, they can introduce them to successful young women of color and those from low-income families who have faced and overcome numerous obstacles on their paths to STEM careers, and familiarize them with available job opportunities. In addition to such initiatives as connecting students with appropriate resources and role models in STEM, promoting STEM in practically oriented and fun ways, and providing insightful materials about STEM (Traurig & Feller, 2008), counselors need to be attuned to the complex problems that underrepresented female students encounter as they consider embarking on STEM careers. They need to take seriously the self-doubt and lack of confidence that even high achievers in math and science feel in the face of engineering (Foor, Walden & Trytten, 2007). They need to seriously consider the dilemmas of economically precarious yet academically promising young women who depend on high grades to receive and maintain college scholarships and who may be a family's primary hope for social mobility. These young women literally cannot "afford" the low grades so famously associated with engineering (Bruning, Bystydzienski, & Eisenhart, 2015; Lopez, 2003). These conditions require counseling, support services, and programmatic efforts that can identify and distinguish the particular obstacles that young women face and address them accordingly.

A sense of community among the young women in the study was an influential byproduct of the project, as the participants remained connected with supportive peers and garnered access to critical services through associations with others. Counselors, mentors, and advisors are encouraged to facilitate the formation of formal and informal networks as they serve to retain and buoy young women who pursue nontraditional educational programs and careers.

References

American Association of University Women. (2010). *Why so few?* Washington, DC: Author.

Bruning, M., Bystydzienski, J., & Eisenhart, M. (2015). Intersectionality as a framework for understanding diverse young women's commitment to engineering. *Journal of Women and Minorities in Science and Engineering, 21.* doi:10.1615/JWomenMinorScienEng.2014007345

Ferrini-Mundy, J. (2013). Driven by diversity. *Science, 340,* 278.

Foor, C., Walden, S., & Trytten, D. (2007). "I wish that I belonged more in this whole engineering group": Achieving individual diversity. *Journal of Engineering Education, 96,* 103–115.

Gott, T., Harris, K., Hoster, J., McFee, M., & Pollock, M. (2013). Improving student access to and awareness of STEM majors. Retrieved from http://www.nacacnet.org/events/2013/edsessions/Documents/SessionB11.pdf

Lopez, N. (2003). *Hopeful girls, troubled boys: Race and gender disparity in urban education*. New York, NY: Routledge/Falmer.

Lubinski, D., & Benbow, C. (2006). Study of mathematically precocious youth after 35 years: Uncovering antecedents for the development of math-science expertise. *Perspectives on Psychological Science, 1,* 316–345.

National Research Council. (2011). *Successful K-12 STEM education*. Washington, DC: Author.

National Science Board. (2012). *Science and engineering indicators*. Arlington, VA: Author.

National Science Foundation. (February, 2013). *Women, minorities and persons with disabilities in science and engineering* (NSF Publication No. 13-304). Arlington, VA: Author.

Stewart, G. L., Russell, R. B., & Wright, D. (1997). The comprehensive role of student affairs in African American student retention. *Journal of College Admission, 154,* 6–11.

Traurig, A., & Feller, R. (2008, December). Preparing students for STEM careers. *Career Convergence Magazine*. Retrieved from http://www.ncda.org/aws/NCDA/pt/sd/news_article/6234/_self/layout_ccmsearch/false