

## **It Takes a Village to Raise an Engineer**

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Carolyn Parker is a STEM education faculty member and researcher at the Johns Hopkins University School of Education. Her work appears in the *Journal of Research in Science Teaching*, *Written Communication*, and *School Science and Mathematics* and the edited volume: *Research on Women in Education Series: Girls and Women in STEM Fields: A Never Ending Story*.

Dr. Parker is a co-principal investigator for JHU's National Science Foundation STEM Achievement in Baltimore Elementary Schools (SABES) grant. The SABES grant is a 7.4 million dollar award that leverages the skills and resources of the schools, community, and businesses in three high-minority, low-resource Baltimore city neighborhoods. The goal is to integrate science into a child's world as opposed to bringing a student into the world of scientists.

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Michael Falk is a Professor in the Department of Materials Science and Engineering at Johns Hopkins University's Whiting School of Engineering where he has served on the faculty since 2008 with secondary appointments in Mechanical Engineering and in Physics and Astronomy. He holds a B.A. in Physics (1990) and a M.S.E. in Computer Science (1991) from Johns Hopkins University and a Ph.D. in Physics (1998) from the University of California, Santa Barbara. He has been twice selected as a visiting Chaire Joliot at the École Supérieure de Physique et de Chimie Industrielles at Paris Tech and has organized extended workshops on the physics of glasses and on friction, fracture and earthquakes at the Kavli Institute for Theoretical Physics. He has received several awards for his educational accomplishments, and in 2011 he received an award from the university's Diversity Leadership Council for his work on LGBT inclusion. His education research focuses on integrating computation into the undergraduate core curriculum. Falk also serves as the lead investigator for STEM Achievement in Baltimore Elementary Schools (SABES) an NSF funded Community Enterprise for STEM Learning partnership between JHU and Baltimore City Schools.

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### Abstract

We present survey results from grade 3-5 students, focused on student understanding of engineering. The work, supported by a National Science Foundation Math Science Partnership between a large, research-focused university and a high need, urban school system, focuses on bringing the work of engineers to the world of inner city elementary students through an engineering focused in-school curriculum, and an out of school-time experience, supported by community partnerships and guided by engineering mentors. One year of student survey data compared to quasi-experimental control groups are discussed. Comparisons of student responses revealed that after one year of the program, students in in the program were able to articulate with greater accuracy what the discipline of engineering is and what engineers do than in the year previous and also in relation to comparable students who had not yet been exposed to the program. These findings have potential positive implications for the impact of community-based partnerships on students' understandings of engineering.

*Keywords:* STEM, engineering, elementary school, community partnerships

Science, and its contemporary companions, technology, engineering, and mathematics (STEM), have been criticized for not meeting the needs of vast numbers of students. However, applying literature from our science education world, there is evidence that access to science and therefore engineering, could be enhanced with a greater integration between in-school and out-of-school settings (Bouillion & Gomez, 2001). Strengthening the integration of the two settings could result in enhanced engineering education for all students (Stocklmayer, Rennie, & Gilbert, 2010; Bouillion & Gomez, 2001).

The integration of science and engineering into the learner's world, as opposed to bringing students into the world of scientists and engineers, has shown to have the potential to support students' science learning, particularly with underserved students (Calabrese Barton, Kang, Tan, O'Neill, Bautista-Guerra, & Brecklin, 2013). Bouillion and Gomez's (2001) study of a community-based education partnership where students solve real-world, community-based problems find positive results including enhanced student learning of science and engineering concepts and skills.

Conceptualizing engineering literacy as a practice within a community requires a community-based effort. Sheldon and Epstein (2004) suggest that integrating subject-specific practices such as engineering into school, family, and community partnerships helps educators improve student skills and achievement. Research also suggests that involving families and communities in learning is a useful support for student achievement, especially in early elementary grades, and studies illustrate the importance for schools located in large urban areas to address obstacles to family and community involvement to realize benefits (Sheldon, 2003).

### STEM Achievement in Baltimore Elementary Schools (SABES)

STEM Achievement in Baltimore Elementary Schools (SABES) is a five-year Community Enterprise for STEM Learning funded by the National Science Foundation (Grant No. DUE-1237992). SABES aims to include schools, communities, and caregivers in meaningful and authentic science experiences that will foster student interest in science and engineering and bolster their achievement in grades 3-5. SABES consists of a curriculum, teacher professional development, an after-school program, and community events.

#### **SABES includes the following components:**

1. A partnership between the Johns Hopkins University and Baltimore City Public Schools (City Schools), focused on improving outcomes, in three demographically distinct neighborhoods situated in the city, by bringing together schools, non-profit afterschool providers, and community-based organizations (CBOs).
2. The in-school component focuses on grades 3-5 where teachers acquire knowledge around STEM content and pedagogy with the support of faculty from the Johns Hopkins Whiting School of Engineering and School of Education. Rigorous curriculum is implemented within a comprehensive system of professional supports. The professional development includes school-level support through coaching, subject-specific courses to increase content knowledge coupled with pedagogical content knowledge, and collaborative professional learning communities (PLCs) in which teachers share best practices and undertake peer visits.
3. The after-school component, run by the schools' existing after-school provider,

builds an understanding of the engineering design process through hands-on explorations. Students engage in an after-school program that focuses on long-term, problem-based, student-directed projects that are relevant to their own lives and communities. STEM faculty and students from Johns Hopkins University help guide the development of the student-driven projects. Investigations in after-school are designed to emphasize the relevance of STEM to students in the three Baltimore City neighborhoods. The JHU faculty and student volunteers are from a range of departments including: biology, biomedical engineering, biophysics, chemistry, chemical engineering, electrical engineering, mechanical engineering, civil engineering, materials science and engineering, and geography and environmental engineering and mathematics. The JHU faculty and students provide the students with exposure to a variety of engineers and scientists and their respective fields.

4. Community-based groups help to organize local STEM events that bring teachers, students, families, other community members, and university-based partners together to celebrate student projects, with the objective of increasing family awareness of STEM topics and career options for their children and providing family members with ways to engage with their children around STEM.

### **Method**

Grade 3-5 students impacted by the project were surveyed before the project began and after one academic year of implementation. Students responded to close-ended questions that examined their attitudes around their understanding and interests in mathematics, science, and engineering, whether they have career aspirations in the STEM field, their perceptions of their peers, teachers and family in support of their

STEM learning, and their perceptions into their own self-efficacy and motivation to learn mathematics and science. Student responses are grouped according to the following broader concepts:

- Intrinsic interest (in science and math)
- Peer support for achievement
- Teacher caring (about students' learning and development)
- Working to meet adult standards (as motivation)
- Interest and understanding of engineering
- Future utility/usefulness of science and math (as motivation)
- Effort (in science and math)
- Self-concept of ability (in science and math)
- Knowledge of engineers and the engineering profession

There was one open-ended item on the fourth and fifth grade survey that asked the students, "What does an engineer do?" This paper discusses the students' responses around interest and understanding of engineering and the engineering profession.

### **Analytical Approach**

We attempt to identify the influence of the project on student knowledge of and interest in engineering. We compare students in schools where the project was implemented for one academic year to students in schools where SABES will be deployed in the future and we compare students in the same school, before SABES implementation and one year after implementation.

We collected survey data from fourth and fifth grade students from these schools. To test whether these differences are statistically significant, we used logistic regression models to predict the child's response. Taking advantage of the project's staggered implementation allows us to address concerns of selection when comparing schools that choose to participate in a program like SABES to other similar schools. Factors that one must take into account are factors such as a principal's commitment to science education or the presence of a one or more strong science teachers, which increases the likelihood that a school might adopt a program like SABES and therefore possibly influence, student knowledge about and interest in engineering are accounted for in this design. By comparing students in schools where SABES has been implemented for a year to students in schools where SABES has not begun, we assume that these more affective but difficult to account for factors are present in all of the schools. To further analyze the possible influence of SABES on student knowledge of and interest in engineering, we also observe students prior to the implementation of SABES and at the end of the first year of the implementation. If the results of the two comparisons are consistent, we have more confidence that the changes that we observe in the students who have participated in the project for one year are attributable to SABES.

We apply these approaches to two types of data from the project's student survey: a set of questions that directly ask students about their knowledge and interests ("I know what engineers do in their jobs," "When I am grown up, I want to be a scientist," and "When I am grown up, I want to be an engineer.")



### Data Collection

The survey data were collected in the three Wave 1 schools in Spring 2013 and Spring 2014 to capture attitudes at baseline and after one year of SABES. The data from the two Wave 2 schools was collected in Spring 2014 concurrent with the Wave 1 schools; these schools adopted SABES in Fall 2014 so these data are also prior to the implementation of SABES. The survey was conducted in classrooms during the school day.

The characteristics of the students in the survey samples are shown in Table 1.

**Table 1: Student Characteristics**

	Wave 1 Schools: Post-THE = PROJECT	Wave 2 Schools: Pre-THE = PROJECT	Wave 1 Schools: Pre- and Post-THE = PROJECT
Female	44%	60%	50%
Free/Reduced Lunch	94%	97%	94%
English Language Learners	12%	11%	17%
Special Education	19%	27%	21%
White	37%	37%	32%
Black	59%	59%	64%
Hispanic	28%	32%	22%
Asian	2%	2%	3%
Number of Students	254	102	137

The student population is majority African-American and nearly all of the students are eligible for free or reduced price meals. Substantial numbers of students receive additional services as well. For example, among the students in the Wave 1 of the project's schools who provided free response answers in two consecutive years (fourth grade and then fifth grade), 50% were female, 94% were eligible for free or reduced price meals, 17% were English Language Learners, and 21% received special education services. Thirty-two percent of students identified as White, 64% identified as African-American, 3% identified as Asian, and 22% reported Hispanic ethnicity. Hispanic ethnicity is reported separately from race; most of the students identified as White also identified as Hispanic.

### **Data Analysis**

The survey directly asked students a number of questions, including three that related explicitly to knowledge about and interest in engineering as a career. We use the answers from three questions: "I know what engineers do in their jobs," "When I am grown up, I would like to be a scientist," and "When I am grown up, I would like to be an engineer." Students were given a choice of Yes, No, and Maybe; we collapse Maybe and No to a single (reference) category for analysis. The proportions reported in the results are those students who chose "Yes" versus "Maybe" and "No."

We first examine the responses from the Spring 2014 survey (see Table 2 and Figure 2).

**Table 2: Wave 1 and Wave 2 SABES Schools in 2014**

"What do you think of when you hear the words <b>engineer</b> or <b>engineering</b> ?"	Wave 1 Schools: Post-SABES	Wave 2 Schools: Pre-SABES	Difference
Acceptable Answer	53%	20%	33%
Positive Response	15%	15%	0%
Wants to be an Engineer	3%	4%	-1%
<i>Types of Acceptable Answers</i>			
Building Things	38%	17%	21%
STEM Related	4%	1%	3%
Fixing Things	10%	5%	5%
Inventing Things	5%	4%	1%
Creating Things	8%	2%	6%
Designing Things	4%	2%	2%
<i>Other Survey Questions<sup>+</sup></i>			
"I know what engineers do in their jobs."	59%	43%	16%
"When I am grown up, I would like to be a scientist."	17%	17%	0%
"When I am grown up, I would like to be an engineer."	15%	6%	9%
Number of Students	254	102	

Notes: <sup>+</sup> Proportion of students choosing "Yes" from Yes/Maybe/No options.

## Results

As Table 2 shows, the proportion of students who offered an “acceptable” answer to the question “What do you think of when you hear the words **engineer** or **engineering**?” was significantly higher in the schools where SABES had been in place for one year. In the schools that had agreed to SABES but had not yet implemented the program, 20% of children offered an acceptable answer. This is not a trivial number of

“acceptable” answers, but in the schools where SABES had been underway for a year the proportion of students with acceptable answers was 53%.

There were no differences in the proportion of responses that demonstrated a positive view of engineering; in both sets of schools, 15% of students offered a positive answer. Similarly, there were no differences in the proportion of students who expressed an interest pursuing engineering professionally (3% and 4%). The three survey questions showed a similar pattern. In the schools where SABES had been in place for a year, more than half (59%) of students claimed to know what engineers do. The rate at the other schools was also high (43%), and the difference is statistically significant. The free response coding suggests that indeed slightly over half of students in the project’s schools know what an engineer does (acceptable answer: 53%), but that the students in the schools where SABES was yet to be introduced had lower levels (20%). This discrepancy suggests that these children may claim to know what an engineer does, but that only a minority—a substantial minority, to be sure—can satisfactorily articulate it. There is an observed difference in the proportion of students who state they wish to be an engineer when they grow up (15% vs. 6%).

To investigate how this difference may have come about, and how legitimate the apparent differences are, we turn to the analysis that follows students from the beginning of SABES to one year in. Among these children, the proportion of “acceptable” answers increased from 28% to 58%, a statistically significant difference. Recall as well that the baseline rate in the Wave 2 schools was 20%, which is not far from 28%, suggesting that the initial conditions are the schools were comparable. As before, most of the increase in acceptable answers was in the “building things,” response, an increase from 19 to 44% that is not statistically significant ( $p = 0.070$ ). Similarly, the students claimed on the survey to know what engineers do; the estimates, which again are only marginally

statistically significant ( $p = 0.069$ ) but similar in magnitude to the other analysis. And once again, the initial level of confidence in one's own response was very high (40%) which then increased to over half (61%).

### **Discussion**

The consistency of the comparisons across the two approaches is gratifying, as it suggests the existence of a real phenomenon that is hinted at in two different ways. The levels of the responses and the differences are similar, which suggests to us that student knowledge about engineering is changing due to the introduction of THE PROJECT. To refer to Figure 1, comparisons A and B appear to be similar. Most of these apparent changes, however, appear to be informational rather than aspirational. That is, after one year of SABES, there appears to be convincing evidence that they know more about engineering than they did before. They claim to be—and are verified to be—better informed about engineering. Whether they will to pursue engineering as a career, however, remains to be seen.

### **Contribution to the Teaching and Learning of STEM**

The need for reform in science education has been trumpeted by many organizations. Recently, The National Science Board issued the report “Preparing the Next Generation of STEM Innovators” (2010), which describes better ways to identify and develop the next generation of "STEM innovators" in the United States. The report suggests that we must "cast a wide net" to seize on historically underrepresented talent including minority students and children from low-income families.

A comprehensive program like SABES, which focuses on bringing the world of STEM to students who have been historically underserved by our educational communities, appears to show promise. After one year of the program, participating

students had better understandings of engineering and engineers than students who did not participate.

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