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Expert View

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Implementation of a Biomedical Engineering Research Experience for African–American High School Students at a Tier One Research University

Enriching science experiences and competencies for underrepresented students during high school years is crucial to increasing their entry into the science pipeline and to improving their preparedness for success in college and STEM careers. The purpose of this paper is to describe the implementation of project ENGAGES, a high school STEM year-long research program for African–American students, mentored by graduate students and postdoctoral researchers at Georgia Tech. It aims to provide an authentic research experience and expose student to the possibility and benefits of attaining an advanced degree and careers in STEM fields. Initial program outcomes include student reported satisfaction with research experience, improved technical skill development, and increased curiosity and interest in STEM careers. Additionally, students indicated increases in college readiness, research skill development, and exposure to STEM careers as a result of interactions with faculty advisors and graduate student mentors, along with laboratory assignments. Lessons learned and potential pitfalls and barriers to acceptance are also discussed. [DOI: 10.1115/1.4040310]

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Introduction

Even with gains in students earning STEM bachelor's degrees over the last 15 years [1,2], jobs for competent scientists and engineers remain unfilled [3]. Moreover, several national efforts are underway to increase not only the number but also the diversity of students going into the field, since there are populations that are underutilized resources who could contribute importantly to scientific innovation and advancement [4]. The least well-represented groups in STEM across all disciplines at the undergraduate level are women, ethnic minorities (African–American, Latinx, and American Indian), and persons with disabilities [2]. According to a 2014 report, African–Americans make up 12% of the U.S. population but are underrepresented at all education levels in STEM fields, earning 8% of bachelor's degrees in science and engineering, and only 3.5% of doctoral degrees in science and engineering [1].

Many factors contribute to these low numbers as reported in numerous studies, with entry into the science pipeline and persistence being two factors we seek to address here. Enriching science experiences and competencies for these students in the high school years is crucial to increasing their entry into the science pipeline and to improving their preparedness for success in college and STEM careers. Persistence in STEM throughout college is significantly lower for African–American students and is correlated with a variety of precollege factors including high school science experiences, rigor of high school curriculum, parent education, and family income [5]. Adequate exposure to science content and development of excitement of scientific inquiry throughout the high school years are important factors in attracting students into the sciences, and ensuring the success and retention of these students in STEM and after college [6].

Engagement of high school students in unique STEM experiences continues to play a profound role in recruiting and retaining bright young minds in the ever-important STEM fields. As such, involving underrepresented students in some form of research or inquiry early in their high school or college education can be a key to success in STEM fields [7–9]. Specifically, hands-on STEM engagement activities foster and maintain positive STEM dispositions at the middle school and high school levels [10]. The U.S. National Science Foundation's (NSF) broadening participation initiatives have sought to encourage and support individuals from underrepresented groups to pursue science-related degree programs and professions [1], often in conjunction with colleges and universities that have created internship, scholarship, and research experience opportunities in STEM. While overarching programmatic goals include increasing interest in and reducing attrition of STEM majors, many underrepresented undergraduate and graduate students partake in such experiences to advance their own skillset [11]. Recently, researchers have argued for the need to offer similar research/apprenticeships experiences and exposure to advanced STEM subjects to underrepresented groups in high school because choosing to major in STEM starts well before college [12]. Such endeavors have been shown to decrease the number of students leaving STEM majors at the postsecondary level, prepare students for their careers, and increase diversity in the field [13–15], addressing both entry into the pipeline and persistence.

Project ENGAGES (engaging new generations at Georgia Tech through Engineering and Science) was started to address these concerns and improve the biomedical, engineering, and STEM workforce by bringing in groups traditionally underrepresented in STEM. Project ENGAGES focuses on African–Americans due to the partnership with Atlanta Public Schools (APS) system, which, as a system is 76% African–American, but is 97% African–American in the project ENGAGES partner high schools according to the Georgia Department of Education statistics for 2014. By encouraging STEM careers earlier, providing hands-on research experiences and training, field-trips to industrial laboratories, and educational support to improve standardized test scores, the goal was to motivate students from these schools to graduate from high school, pursue a path to college, graduate with a STEM degree, and choose a STEM career. To additionally motivate these young people to participate in biotechnology and engineering research at Georgia Institute for Technology (GT), a paid hourly wage, higher than minimum wage, was offered as an incentive. Project ENGAGES offered paid employment to avoid the possibility of this being the selection factor, exclusionary of those that feel a need to acquire paid work to support their families once they reached legal age and in lieu of paid employment at a retail or fast food facility. Additionally, the partner high schools provide free lunch for all students' due to the socioeconomic status of the families.

Research experience opportunities for students to increase their success and persistence, as mentioned earlier, are not an original concept, but what is unique about project ENGAGES is the combination of three key aspects: (1) focus on African–American high school students, (2) year-long research experience beginning in summer and continuing through academic year, and (3) compensation during research experience as an employment experience. The purpose of this paper is to share the implementation and formative evaluation of a high school STEM research experience program that aims to provide an authentic research experience for African–American high school students and expose them to the possibility and benefits of attaining an advanced degree and careers in the STEM fields. Next, we briefly share some initial program outcomes and how those findings on the scholars and the mentors suggest important aspects to keep and others to improve for future years of the program's success.

Project ENGAGES: A High School STEM Research Experience Program. Project ENGAGES is a high school science research and educational program developed at GT by faculty as part of the NSF funded Emergent Behaviors of Integrated Cellular Systems (EBICS) Science and Technology Center. GT labs included professors and principal scientists from biomedical engineering, mechanical engineering, chemical engineering, biology, and chemistry.

Project ENGAGES began as a partnership with the Coretta Scott King Young Women's Leadership Academy (CSKYWLA) and Business, Engineering, Science, and Technology (B.E.S.T.) Academy at Benjamin E. Carson in 2013, two public high schools in the city of Atlanta, and then was expanded to KIPP Atlanta Collegiate in 2014, and now includes six partner high schools. Georgia Tech is located in midtown Atlanta with these APS high schools in close proximity within a four to five mile travel distance; this is important for students' transportation to Georgia Tech not only for the summer portion, but also for the academic year period in which they are expected to work 12–16 h per week. In 2015, only 71.9% of students in APS were graduating from high school, compared to the Georgia state average of 79% [16]. A partnership with GT was, in part, a plan to raise the achievement bar, enhance college acceptances, and promote STEM careers for their students. The overarching goal of project ENGAGES is to educate and train underrepresented minority high school students in cutting-edge research in biomedical, chemical, or mechanical engineering, and associated sciences.

For consideration as an ENGAGES scholar, students must complete an online application with a personal statement, resume, and two letters of recommendation, one of which must be a science teacher. They also must have a 3.0 or an 83 GPA to apply for the program. Then, candidates are selected for a 20 min in-person panel interview, composed of GT professors, an academic leader from one of the schools (such as assistant principal), GT graduate students, and ENGAGES program manager. Selected students are then chosen from that pool.

To adequately prepare these high school students for the technical aspects and professional aspects of working in research labs, ENGAGES scholars first participate in a four-week "bootcamp" at

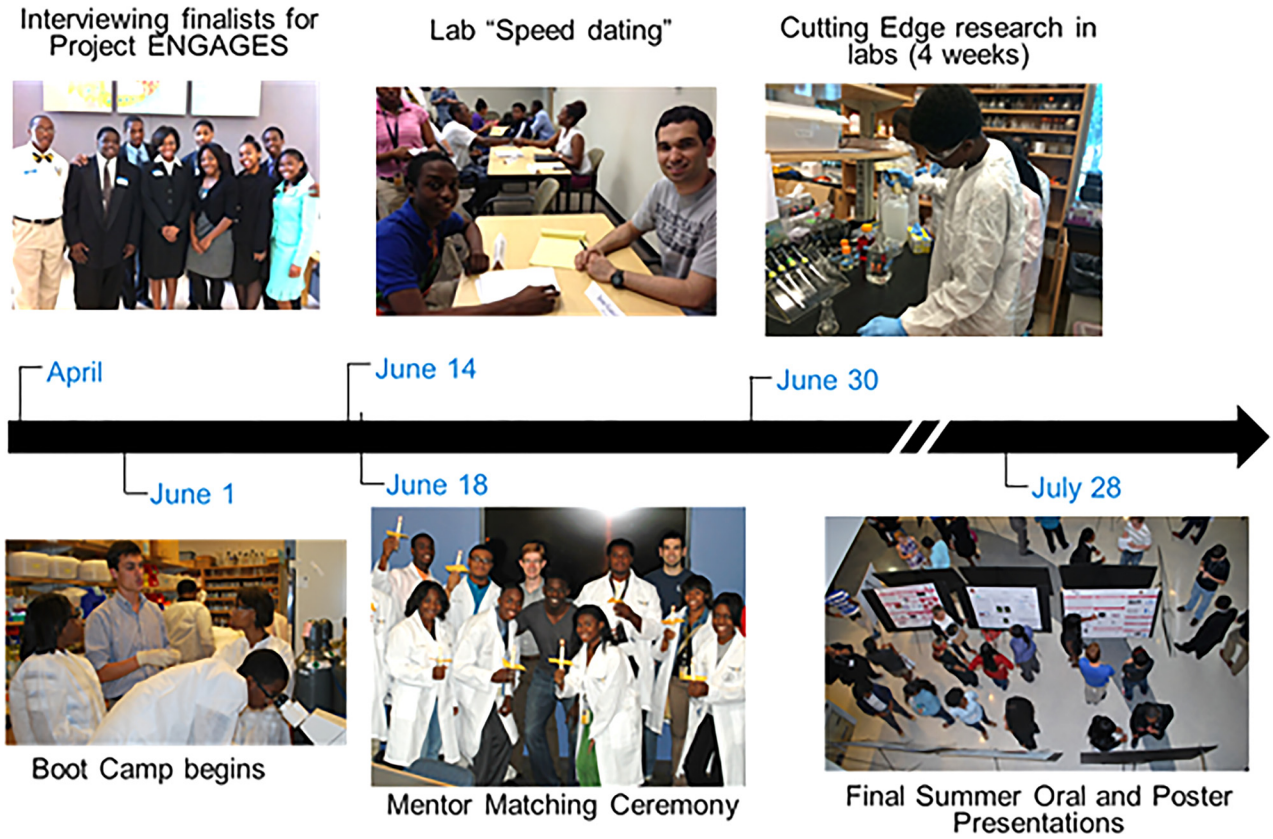

Fig. 1 Summer timeline of project ENGAGES from applicant panel interviews through to final summer presentations. Panel interviews occur in April after online applications were reviewed, then selected students begin boot camp for the first 4 weeks. In the middle of bootcamp, scholars and mentors participate in a speed dating exercise to determine fit followed by a mentor matching ceremony. ENGAGES scholars work on research projects and develop both oral and poster presentations for the end of summer symposium.

the beginning of their employment June 1. The first bootcamp was developed in 2013 and taught by teachers from the ENGAGES partner high schools. This bootcamp curriculum was developed in conjunction with teachers from the two high schools and ENGAGES program leadership to integrate classroom lectures with hands-on lab technique training relevant to broad biotechnology and engineering related projects. Initial planning was based on input from teachers, and drawing on our own experiences and intuition as African–Americans that obtained Ph.D.s in STEM fields, and also as professors in STEM with knowledge of what we thought would be important for project ENGAGES students to learn to overcome initial barriers to entry for their placement and productivity in a research lab. The goal was to provide a foundational experience, knowledge base, and lab safety trainings to ease their transitions into their research laboratories with an aggressive timeline to prepare students to work in engineering and science research labs (Fig. 1). Lab safety training classes are all official courses taught by Georgia Tech's Environmental Health and Safety Office and include General Lab Safety Training; General Biosafety; Bloodborne Pathogens Safety Training; and Recombinant DNA Safety Training.

Students were then matched with research labs, graduate student or postdoctoral researcher mentors, and faculty advisors based on a "speed-dating" method where both research mentors and ENGAGES scholars provide rank ordered listing of preferences. Briefly, mentors are set up at separate tables around a large room with their name on a placard in front of them. Students have their own name plate that they take with them as each student spends 4 min of interview time with each of the potential mentors, followed by an announcement to switch and everyone rotates by one mentor. At the end, each student and each mentor generates a rank ordered list of preferences, and matches are made taking those rankings into account. To reveal the matches, we held a mentor matching ceremony with each ENGAGES mentor draping monogrammed white lab coats over their ENGAGES scholar, reflecting the White Coat Ceremony of medical schools [17]. Then, their 12 month research apprenticeships began and continued with a lab identity and affiliation. Professional development seminars and workshops include responsible conduct for research ethical training, diversity and inclusion training, and preparation of written, visual, and oral presentations, applying to college, SAT and ACT examination preparation, how to make a professional poster and conference presentation workshops among other exercises.

Academic year research. Upon successful completion of the summer experience, the high school students are encouraged to continue this research during the academic year. Arrangements were made with the high schools to allow their students to leave after lunch to allow them to dedicate 12–16 h per week of lab time at GT and still be able to return home by dinner time to spend sufficient time on their homework to maintain their excellent academic performances. Project ENGAGES research symposia are held at the end of the fall, spring, and summer semesters. Family, friends, school administrators, and GT researchers and upper administration are invited to all project ENGAGES symposia.

Research project titles span biomedical and other engineering disciplines including the following examples:

(1) The fluid mechanics of taste—mechanical engineering lab investigating the adhesive and fluid properties of anteater saliva.
(2) Mobilizing brain cancers with stimulation from electric fields—biomedical engineering lab studying glioblastoma migration after stimulation of the brain in a rat model.

(3) Cathepsins K, L, S intracellular localization in transfected HEK-293T cells—biomedical engineering lab with the purpose of investigating how overexpressing a class of proteases for purification affects their localization and cell health.
(4) Regenerating articular cartilage with heparan sulfate hydrogels using human adipose derived stem cells—biomedical engineering lab using adult stem cell culture with biomaterial strategies to generate cartilage, and then test the biological and mechanical properties of that cartilage.
(5) Modeling the effects of Bruch's membrane opening shape on the biomechanics of the rat model of glaucoma—computational modeling of anatomical features of the eye to assess pressure and other biomechanics involved in glaucoma progression.
(6) Fluid and structural biomechanics of lepidoptera antennae—mechanical engineering lab investigating biomechanics of butterfly antennae for bioinspired design.
(7) Immuno-modulatory hydrogels for stem cell therapy after traumatic brain injury—biomedical engineering lab seeking to mitigate macrophage infiltration after brain injury with biomaterial strategies to modulate their activity.
(8) Applications of piezoelectric harvesting technology—mechanical engineering lab developing technology to capture the mechanical energy from walking or stepping on piezoelectric materials and convert it into stored electrical energy.
(9) Development of a heat polymer generator for energy production—mechanical engineering lab developing materials to convert heat into electrical energy and store it.
(10) Exploring the pro-regenerative actions of resolvins—biomedical engineering lab studying the influence of bioactive lipids on adult stem cell regenerative potential.
(11) The impact of microenvironment stiffness on lymphatic muscle cell function—mechanical engineering lab performing studies on biomechanical responses of smooth muscle cells of lymphatic vessels and how the mechanics of the environment influence cell behavior.
(12) The effect of surface stiffness on mesenchymal stem cell function—biomedical engineering lab using biomaterials of different stiffnesses to influence adult stem cell differentiation.

Methods

Twenty nine students were active participants during the 2014 summer project ENGAGES cohort when this evaluation was completed. Students were from B.E.S.T Academy High School, CSKYWLA High School, and KIPP Atlanta Collegiate High School. Twenty of these students were new students, and nine of these students were returning students. Returning students were those who began project ENGAGES summer 2013 as rising juniors and were now entering their senior year of high school. Of the new students beginning in summer 2014, 12 were rising seniors who would have one year in ENGAGES, and four were rising juniors that would be able to complete two years in ENGAGES.

Evaluation Approach. To evaluate the effectiveness of project ENGAGES implementation, external evaluators utilized a Values-Engaged, Educative evaluation approach [18–20]. The Values-Engaged, Educative approach, developed with NSF-EHR support, defines high-quality STEM educational programming as that which effectively incorporates cutting-edge scientific content, strong pedagogical instruction, and sensitivity to issues of equity and diversity. The evaluation was conducted on a formative basis, meaning its intent was to provide feedback for improving implementation of project ENGAGES during its development and delivery. A mixed-methods evaluation design was employed. Multiple data collection methods and sources were employed to obtain information. Data sources included observations, project ENGAGES scholar surveys, focus groups, scholar pre-and-post assessments, and a graduate student mentor survey. All evaluation activities were approved by the University of Illinois Institutional Review Board and all participants signed consent forms. Co-authors Destefano and Boyce were affiliated with University of Illinois at the time these evaluations were conducted.

Project ENGAGES Scholar Surveys. Scholars anonymously completed three online satisfaction surveys related to the overall experience, including resources given, professional development, laboratory and research assignment, items related to campus location, and successfulness of the program. The first survey was given at the beginning of the program, the second was conducted at the midpoint, and the final at the end of the program. The surveys included both closed-and-open ended items. Closed-ended questions consisted of five-point Likert-type scales from "very dissatisfied" to "strongly satisfied" and "not at all useful" to "very useful." Descriptive statistics were calculated for each rating area and reported. A total of 29 scholars completed each survey (Table 1).

Observations. Observations were conducted throughout the project ENGAGES program. The purpose of these observations was to generate data to describe activities, engagement between faculty/trainees with each other and with the activities, to informally interview participants, and to collect artifacts distributed to participants. Moreover, evaluators noted information related to the following categories during the observations:

- *Physical setting*—a rich description of the time and locale of the event, including where participants were situated.
- *Social or interpersonal setting*—who was clustered with whom and how groups and individuals were arrayed in this context.
- *Activities*—a systematic description of the activities with timeframes.
- *Content*—a description of the resources and materials used and discussed.
- *Interactions*—a description of verbal and nonverbal interactions between various stakeholders.

Project ENGAGES Scholar Pre-and-Post Assessment. A pre-and-post assessment was administered to each scholar to self-rate their perceived level of gains in understanding research and the skills required to do research. To test for statistically significant changes from pretest to posttest, paired sample *t*-tests compared preprogram and postprogram means. We considered findings significant at $p < 0.05$.

Project ENGAGES Scholar and Mentor Focus Groups. Focus groups were also conducted with the scholars and the graduate students/postdoctoral mentors by independent evaluators separate from the ENGAGES program leaders. Protocols were developed and followed during the focus groups to prompt interviewees in order to ensure that the relevant questions were covered.

Graduate Student and Postdoctoral Fellow Mentor Survey. After scholars completed the summer segment of the project ENGAGES program, graduate student/postdoctoral fellow mentors were asked to complete an online survey. The survey was used to obtain information about mentors' perceptions about the project ENGAGES program. Specifically, they were asked about their satisfaction with the ENGAGES scholars' placement in the laboratories, their understanding of program goals, and their thoughts about perceived benefits of the program for the participants. A total of 13 mentors completed the survey.

Table 1 Project ENGAGES Summer 2014 Scholars' Gender and High School Affiliation

Gender	BEST	CSKYWLA	KIPP	Total
Male	10	0	4	14
Female	0	14	1	15
Total	10	14	5	29

Results

Scholar Satisfaction. Scholars were asked to rate their satisfaction with overall experience, networking opportunities, graduate student mentor interactions, faculty advisor interactions, research project, the GT campus professional development, social outings, orientation, pay rate, and other project ENGAGES participant interactions on your campus (OPEPI). All scholars indicated that they were satisfied or very satisfied with their overall summer ENGAGES program experience, with an average score of 4.9 (Fig. 2). The components with the highest ratings were networking opportunities, interactions with their graduate student/postdoctoral mentor, interaction with faculty advisor, and research project/lab assignment. Scholars also participated in field trips and professional development activities throughout the program. A majority of students reported these events as being useful, particularly for increasing their college readiness and exposure to STEM careers in industry and academia (Tables 2 and 3).

During focus groups, scholars indicated activities related to preparing for college and learning about life as an undergraduate student to be most useful. Notable comments included, "the college preparedness and undergraduate session because they made me realize I need to be better at being diligent and on my studies" and "the preparing for college professional development was useful. They got me prepared for what to expect when I graduate from high school."

Scholar Interactions With Faculty Advisors and Graduate Student/Postdoctoral Mentors. At the end of the summer experience of Project ENGAGES, survey results revealed all scholars were very satisfied or satisfied with faculty advisor interactions. The average overall rating was 4.72 out of 5, with 72% of students indicating very satisfied. One student commented, "the faculty takes our opinions and feedback then help make our experiences here better." Approximately 50% of scholars reported communicating with their faculty advisor on a daily basis through various modes of communication, such as in-person, email, phone, and text messaging. The vast majority of students, 97%, were also satisfied or very satisfied with their graduate student/postdoctoral mentors. More than half of scholars communicated daily with their mentor. Face-to-face interactions and email were the most commonly used methods of communication.

Table 2 Scholar final survey: Scholar rating of professional development usefulness ($N = 29$, range 1–5, lowest to highest)

Activity	Mean	Standard deviation (SD)
Field trips[a]		
Company 1	4.30	±1.03
Company 2	4.21	±1.21
Company 3	3.81	±1.22
Professional development		
College preparedness session	4.56	±0.93
Undergraduate panel—talking about their journey in STEM	4.32	±0.90
Faculty guest speaker	4.18	±0.85
Bootcamp	4.11	±1.01
Ethics module	3.92	±1.19

[a]Company 1 and company 2 are large Fortune 500 companies, and company 3 was an early stage start-up company at the time of this evaluation.

Scholar Laboratory Experience. Survey results indicated that scholars were satisfied or very satisfied with their research projects and lab assignments. Scholars stated that the laboratory experience was the most exciting aspect of the project ENGAGES. Scholars expressed that the laboratory experience increased their interest in science and had given them a better understanding of what engineering and biotechnology scientists do. Working in the laboratory also increased their curiosity and self-confidence, indicating achievement of a project ENGAGES program goal. Additionally, scholars in their second summer (the returning students) commented on their laboratory experience as giving them an opportunity to work independently and being able to immerse themselves in the research culture. Noteworthy comments included:

The most exciting thing is I really feel like I'm immersed in the research culture now. And that's progress, like when you get wiser and mature! I feel like the same thing is happening to me in lab. So that's the best thing this summer.

This summer has actually been more intense for me. I feel like the more you grow, the more people expect from you. And that has changed since last summer. I have higher expectations of myself. Last year my research project was good, but the one this year is excellent, and I am proud of that.

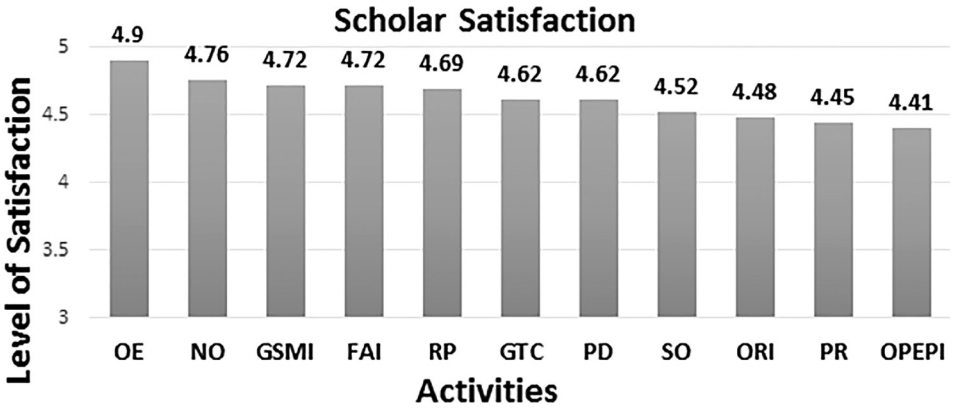

Fig. 2 Level of satisfaction (mean) reported by scholars for project ENGAGES activities ($N = 29$). Overall experience, networking opportunities, graduate student mentor interactions, faculty advisor interactions, research project, the GT campus, professional development, social outings, orientation, pay rate, and other project ENGAGES participant interactions on your campus (OPEPI).

Table 3 Graduate student mentor satisfaction with scholars ($N = 13$, range 1–5)

Question	Mean	SD
Working with high school researchers was a rewarding experience.	4.38	±0.87
I feel that my project ENGAGES scholar understood the research project.	4.23	±0.60
I am satisfied with project ENGAGES scholar's poster.	4.15	±0.80
I am satisfied with my project ENGAGES scholar's final presentation.	4.15	±0.80
I developed a mentoring relationship with the student(s) that will last beyond the summer experience.	4.0	±1.0
I am satisfied with my project ENGAGES scholar's final paper.	3.58	±0.67
Working with high school researchers positively contributed to my research agenda/process.	3.54	±0.97

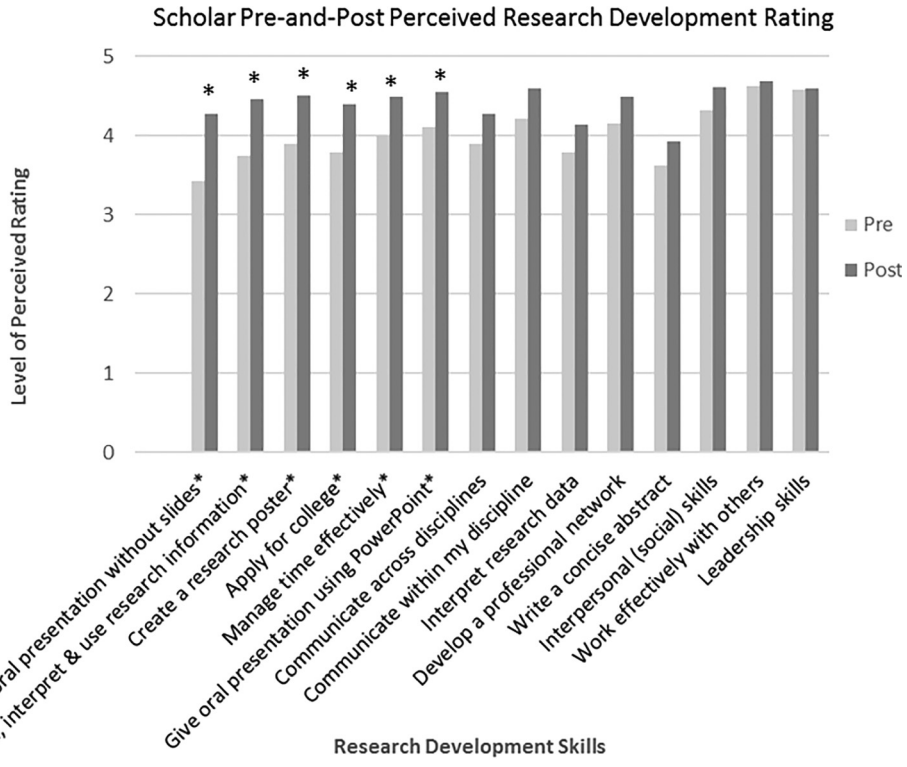

Fig. 3 Average scholar self-rating of pre-and-post research development skills. Self-assessment ratings by scholars of their own skills before entering and exiting the summer portion of project ENGAGES. Ratings range from 1 (very weak knowledge or skill) to 5 (very strong knowledge or skill). *, $p < 0.05$, postscore compared to pre-score.

Scholar Research Development. Scholars were asked to rate their skills before entering and exiting the summer portion of the ENGAGES program. Ratings ranged from 1 (very weak knowledge or skill) to 5 (very strong knowledge or skill). At the end of the summer, scholars self-reported having a better understanding of research and the necessary skills to conduct research after participating in project ENGAGES (Fig. 3). When asked how this experience affected them as a researcher, many scholars reported that they got a glimpse of graduate school, research life, and gained laboratory and presentation experience. A *t*-test indicated that increases in perceived knowledge or skill to be statistically significant in giving an oral presentation with or without slides; read, interpret, and use research information; create a research poster; applying for college; and managing time effectively.

Matriculation to College and Undergraduate Major. Of the 29 ENGAGES scholars included during this study of summer 2014, 28 of the 29 attended college and declared STEM majors on their college applications; one joined the U.S. Army. This study includes students across three high school graduation years: 2014–2016. Biology (including neuroscience, premed, and kinesiology) was chosen by 15 scholars, an engineering discipline by eight scholars (biomedical, chemical, civil, electrical, industrial, and mechanical). Other majors were chemistry, physics, psychology, forensic science, and recreational therapy. A majority of scholars (19) enrolled in colleges and universities in the southeastern region of the U.S., with 15 in Georgia; 13 as part of University System of Georgia, the public college, and university system; and two attending private colleges in Georgia (Spelman and Agnes Scott, both private women's colleges). Colleges and universities outside of this region included Dartmouth, Bard, Stanford, Johns Hopkins, University of Pennsylvania, Michigan, Brandeis, Albion, and Howard. We will continue to follow Scholars' progress toward their undergraduate degrees and chosen majors. In the meantime, it is our hope that our findings will be useful to similar programs.

Graduate Student Mentors' Program Satisfaction. Overall, 85% of graduate student mentors reported satisfaction with the project ENGAGES program structure, organization, and their understanding of the program goals and expectations. Furthermore, 85% indicated satisfaction with the amount of communication between themselves and program managers. A concern noted by mentors was the availability of information regarding program

timelines and activities scholars were required to attend. Graduate students expressed frustration when their students were not in lab due to mandatory attendance at a program event or professional development activity. As a result, mentors suggested a Google calendar listing all project ENGAGES events.

Graduate Student Mentor Satisfaction With Scholars and Perception of Skills Gained. Results from graduate student mentors survey (Table 3) revealed working with high school researchers was a rewarding experience, with an average score of 4.38 and 92% of students rating a 4 or 5. Students averaged 4.15 in satisfaction with their mentee's research poster and final presentations.

Noteworthy comments around these concepts:

I guess my big thing—my expectations are pretty well matched. Exceptional student. And the pace is about right. But the focus has been a lot on training and not actually executing experimental work. Which is fine for me because I was planning on that.

Experience mentoring helped me to evaluate my own strengths and weaknesses. I feel like I have a good connection with my mentee and I'm excited to see what we can get done in the fall.

With a matching comment from a scholar:

I love my mentor. He's like the big brother I never had. He teaches me a lot of things. I say a lot of crazy stuff, but he knows my way of learning so explains things slowly and pictures.

As a result of these findings reported here, we have worked to provide more information to graduate student mentors about Scholars' schedule and have continued to refine organized activities for Project ENGAGES Scholars including STEM and college preparedness related structured professional activities and social outings.

Discussion

In this paper, we report initial findings from the implementation and formative evaluation of a high school STEM research experience program that aims to provide an authentic research experience for African American high school students from APS and research mentoring by graduate students and postdoctoral fellows. All of our findings can be organized into five overarching themes:

- *Organization*. Program organization and structure was well-received by participants. Additional information about program timelines and scheduled activities are warranted.
- *Interaction with Advisor and Mentors*. Scholar satisfaction of interaction with faculty advisors and graduate student mentors is very high. Nonproject ENGAGES affiliated graduate and undergraduate students have stepped in to support scholars in the laboratory.
- *Laboratory/Research Experience*. Mutual satisfaction with laboratory assignment and experience was expressed by scholars and graduate student/postdoctoral mentors. Scholars in their second year with project ENGAGES have noticeably grown as researchers.
- *Participant Development*. Substantial technical skills were gained a result of the project ENGAGES program. Additionally, scholars' presentation and communication skills improved throughout the summer.
- *Matriculation to College*. Most ENGAGES scholars are matriculating to college and choosing STEM careers.

Increasing interest, and skills and educational development are an important initial outcome and goal of project ENGAGES. However, these are not the only components that will drive success for students from underrepresented groups in STEM fields [8–11]. There is an important role for mentorship and successful mentors willing to invest time in the research training and support for the development of independent research projects [21,22].

The question of whether working with high school researchers positively contributed to the mentors' research agenda/process was the lowest scoring with an average of 3.54. From Table 3, we have another interesting finding in that although the mentors ranked ENGAGES scholars' contributions to their research agenda as lower than other outcomes, the mentors agreed with a score of 4.38, the highest score among the satisfaction categories, that working with high school researchers was a rewarding experience. As planners and organizers of ENGAGES, our hypothesis was that ENGAGES scholars being valuable additions to progress on the mentors' research projects would help to be a motivator to inspire retention of mentors in the program, and for them to recruit their research colleagues and friends into mentoring other scholars. This result can be interpreted that the benefit received/perceived by the mentors was more intangible, the sense of helping out a future scholar or one from a disadvantaged background seemed to override the concern for maximal research productivity as a meaningful and important benefit of being a mentor. This mentor–mentee relationship is one that should be optimized for maximal benefit of experience for both parties.

Conclusion

Our world increasingly relies on science and technology to solve many of today's most difficult problems. As challenges mount in the areas of national defense, climate change, health, energy, economic growth, food safety and accessibility, and environmental protection, so does the demand for highly skilled scientists, engineers, and health professionals [23]. Scholars, policymakers, and laypersons all agree that women and minorities are an undertapped resource to science innovation and advancement in the U.S. [4]. Efforts continue gaining traction in the recruitment and training of these individuals for a number of reasons: increased advances in healthcare and other technologies, increasing the vitality and creativity of STEM projects [24], U.S. continuing to be a player in the global economy [25], and more personally, improving quality of life for the STEM worker through enhanced individual economic opportunity [26,27]. Project ENGAGES is a meaningful experience that informs and encourages students not only to learn about STEM fields but also to actively engage in science processes through hands-on research experiences and training, field-trips to industrial laboratories, and educational support to improve standardized test scores with goal to motivate students from these schools to graduate from high school, pursue a path to college, graduate with a STEM degree, and choose a STEM career.

Along the way, we have also identified a number of potential pitfalls and barriers to acceptance along the way that can be informative for other institution seeking to implement this type of program on their own. Among them, we found that diversity and inclusion training was critical for integration of the African–American students into the demographics of the Georgia Tech graduate students and research labs, and also for the mentors to understand their own inherent bias. Professor investment in supporting the mentor's successful mentoring of the ENGAGES scholar has also been shown to have improved outcomes. One other important outcome to consider are the institutional policies around working with minors. Relationships with the school districts and the administrators at each partner school are also important for constructing student schedules and leaving policies such that they will be able to work their 12–16 h during the academic year. Fundraising to support the salary of these students is of course a consistent need, and there can be many models of success. We have used a combination of federal funds through grant and large center programs, philanthropy from private individuals, and grants from nonprofit organizations or philanthropic arms of corporations. Despite these challenges, the benefits of endeavors such as project ENGAGES will be relevant to the larger community, in addition to the personal pride of mentoring a young person along their path to a productive, exciting career in STEM.

Acknowledgment

None of this work would have been possible without our wonderful students that are the project ENGAGES scholars, their

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