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ORIGINAL PAPER

Aerial Drone: an Effective Tool to Teach Information Technology and Cybersecurity through Project Based Learning to Minority High School Students in the U.S.

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Abstract
This paper describes the design, implementation, and results of an NSF funded Summer Academy from 2016 to 2018, which engaged, on an annual basis, 30 to 60 rising 10th and 11th grade high school science students in an innovative, technology-enriched Project Based Learning (PBL) environment. This Academy emphasized how tech gadgets work and the impact that technology can have on improving communities by immersing students in the exploration of one such device that is a growing phenomenon, the "aerial drone." In this Academy, the students learned various operations of the drone through Python programming language, and some cybersecurity issues and solutions. The student teams, under the guidance of diverse mentors, comprehensively fortified their STEM problem-solving skills and critical thinking. Both formative and summative evaluations for this Academy showed that it helped students improve their critical thinking ability and motivated them to pursue careers in STEM-related disciplines, specifically in information technology and cybersecurity areas.

Keywords Drone · Minority students · K-12 computer science · STEM interest · Cybersecurity

This paper describes the design, implementation, and evaluation results of an NSF funded Summer Academy from 2016 to 2018 that engaged, on an annual basis, 30 to 60 rising 10th and 11th grade high school science students in an innovative, technology enriched Project Based Learning (PBL) environment. The Summer Academy was implemented as a partnership of a Historically Black College and University ("HBCU") and its Engineering and Computer Science Alumni Associations ("HBCU AA"), a Research University ("RU"), and a rural and an urban school district in the historic Black Belt region of the southeastern United States. The focus of the partnership was to recruit annually a cohort of 30 ethnically and racially diverse high school students ("scholars") and 5 teachers from the partnering school districts for immersion in a STEM intensive PBL four-week "STEM Summer Academy."

This comprehensive Academy was designed to provide high school students and teachers with far-reaching technological experiences through exploration of aerial drone application under a PBL framework. In this PBL environment, purposeful "driving questions" that integrate aerial drones were investigated by Scholar teams under the guidance of diverse mentors from the HBCU and the industry to comprehensively fortify STEM problem-solving skills and critical thinking. America's youth are surrounded by technology related products, such as smartphones, tablets, computer games and interact daily with social networking

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sites and the internet. Technology's omnipresence in their daily lives provides them with endless possibilities to communicate, play, and relax. However, as end-users, students are rarely motivated by their peers or teachers to learn how these devices work and to seriously consider career pathways that lead to lucrative industry jobs as computer scientists, information security engineers and technicians that design and maintain such devices (Mouza et al. 2016).

This project emphasized how tech gadgets work and the impact that technology can have on improving students' communities by immersing students in the exploration of one such device that is a growing phenomenon, the fascinating "aerial drone." Scholars identified problems that affect the communities where they live, and formulated driving questions that integrate the aerial drone to forge solutions to these problems. Examples of driving questions include:

- [Agriculture] How can drone technology help my community to map the geographic landscape that is suitable for farmers to grow crops?
- [Ecology] How can drone technology help my community to find discarded waste products in uninhabited areas?
- [Transportation and Weather] How can drone technology help my community to find safe routes for school buses after a flood?
- [Health] How can drone technology be used to deliver medical supplies to an emergency in my community?

The driving questions were introduced at the outset of the Academy. Mentors, who included the HBCU faculty, its Computer Science (CS) graduate and undergraduate students, teachers from participating high schools, and industry representatives from the HBCU and HBCUAA, guided and mentored the Scholar teams in devising a plan to address these problems using their aerial drones. This investigation was performed during the length of the four-week Academy. Scholars gained critically important peripheral STEM-related experiences including: (a) Python programming in operation of aerial drones; (b) Teamwork; (c) Basics of malware and encryption; (d) Collaboration through cloud computing; (e) Best practices in using technology through mini-courses; and (f) Preparation of e-portfolios of daily tasks, for posting as YouTube videos for broad dissemination. In the aggregate, the proposed Academy activities were designed to encourage Scholars to seriously reflect on the benefits of choosing educational pathways that will lead to lucrative STEM-related careers and occupations as technicians. The following subsections provide justification for engaging minority high school students in this Summer Academy.

The Participation of the U.S. Population in STEM Education and Workforce

Despite an intensive drive over the past two decades to orient more students, particularly women and minorities, towards STEM disciplines, the STEM workforce has not diversified itself during this period (Funk and Parker 2018; Varma 2018). Although white and Asian individuals now make up a smaller proportion of the nation's workforce (69% collectively, compared with 74% in 2001), they still dominate the representation in STEM fields: 87% of the engineering workforce and 84% of the computing workforce. African-American and Latino workers now represent 29% of the general workforce, up from 24% in 2001, but just 12% of the engineering workforce and 15% of the computing workforce, rates that have remained essentially unchanged over the past two decades. Woman participation has also seen no improvement in the last 15 years. In 2014, women represented only 24% of the engineering workforce (down from 25% in 2001) and a low 36% of the computing workforce (flat since 2001) (Noonan 2017).

The poor representation of minorities and women in the STEM workforce can be partially explained by a low production of degrees in STEM disciplines for these groups. In 2011, only 36% of STEM bachelor's degrees were conferred on women. Besides, only 7% of all STEM bachelor's degrees were awarded to African Americans. In an encouragingly sharp contrast however, data going back to 1985 reveals that African American freshmen consistently have been pursuing STEM majors at a higher rate than their white peers. In fact, during the period 1985 to 2012, an average of 36% of African American freshmen and 33% of white freshmen declared their intentions to study a STEM subject in college. These data reveal that African American high school students and college freshmen are more interested in STEM fields than their white counterparts, but that the initial interest does not translate into an analogous representation of college graduates in these fields. Studies reveal that a low graduation rate among African-Americans majoring in STEM fields, rather than a lack of interest or desire on their part for studies in STEM areas, seems to be a significant contributing factor for their under-representation in STEM education and in the workforce. This suggests that a mechanism should be put in place to create awareness among all students about (a) The high school STEM preparation needed to succeed in STEM college tracks and that interest in STEM alone is not sufficient for success; and, (b) The types of work that STEM professionals engage in. This is especially critical among future first-generation college students.

A similar phenomenon is observed among girls. A Girl Scout Research Institute study (Modi et al. 2012) reported that, while a majority of today's girls have a clear interest in STEM, they don't prioritize STEM fields when considering their future careers. The study shows that 74% of teen girls are interested in STEM subjects and the general field of study. This is supported by the fact that high school girls take Mathematics and Science courses in near equal numbers as boys do (National Science Board 2018). Further, a high 82% of girls see themselves as "smart enough to have a career in STEM." Yet, few girls consider it their number-one career option: 81% of girls interested in STEM are interested in pursuing STEM careers, but only 13% say it is their first choice. Additionally, girls express that they don't know a lot about STEM careers, with 60% of STEM-interested girls acknowledging that they know more about non-STEM careers than they do about STEM careers. A recent report (State of Computer Science Education 2019) indicated that only 45% of the high schools in the U.S. teach Computer Science, and minorities and females are underrepresented in these classes. This project is an attempt to bridge this gap.

The Lack of Adequate Workforce in IT and Cybersecurity Areas

While job growth in STEM fields, specifically in IT (Information Technology) and IS (Information Security), has been consistently on the rise, diversity in these workforce fields has not grown at a comparable pace. One factor that has contributed to this gap is that minority students have not received an adequate exposure and training in the technology skillset relevant to IT and IS (Burrell 2018; Lachney et al. 2019). There have not been extensive programs to engage minority students in these areas early in their careers, which has resulted, not just in a lack of interest in this field, but also a lack of foundational training that will prepare the students for higher studies and eventually a career in IT and Security. Next, we describe the importance of cybersecurity to any STEM professional in general and IT professionals in particular.

In September 2016, Yahoo confirmed that data associated with at least 500 million user accounts had been stolen by an individual acting on behalf of a government (Cheng et al. 2017). This breach is believed to have occurred in late 2014 and is perhaps the largest security breach ever. Victims of major data breaches in 2016 include U.S. Department of Justice, U.S. Internal Revenue Service, Verizon Enterprise Solutions, Philippine Commission on Elections, LinkedIn, Oracle, Dropbox, and Cisco, among others (Gudivada et al. 2018).

Cyber-attacks cut across private businesses, industries, government organizations, and military establishments. Headless worms, machine-to-machine attacks, jailbreaking, ghostware and two-faced malware are some of the terms used to describe these attacks (Nandakumar and Lakshmi 2017). In the coming years, it is expected that hackers will mount increasingly sophisticated attacks on everything from power grids, nuclear installations, air traffic control systems, to self-driving cars. With the ubiquity of Internet of Things (IoT) networks, mobile computing, and cloud-hosted computing platforms, damage unleashed through cyber-attacks could be lethal and widespread.

Cyber-attacks are exacerbated by several factors. First, several cybersecurity systems operate in a reactive mode without a formalized plan for dealing with cyber-attacks. For example, in the 2015 annual report to the U.S. Congress, federal agencies scored an average of 72% on the ability to detect unauthorized hardware, 74% in anti-phishing defenses, and 52% in Information Security Continuous Monitoring (ISCM) vulnerability management capabilities (Office of Management and Budget 2016). Second, for the most part, cybersecurity is a catch-up game and hackers seem to be well ahead of the defenders. Third, approaches for solving cybersecurity problems are not adequately agile and self-learning. As the saying goes, a chain is only as strong as its weakest link. For example, many organizations outsource website development to third-party developers, who are not particularly security-aware (Cervantes et al. 2016). Such applications can expose the entire enterprise to attacks. Lastly, there is a dearth of well-trained cybersecurity engineers. Cybersecurity unemployment rate is expected to remain at 0 % while the market continues to increase to $125 billion in 2020 (Cohen et al. 2017). Hence the imperative need to generate student interest in cybersecurity - a critical and highly relevant subject - early in their careers.

Framework Guiding the Project Design

Project Based Learning

Over the past few decades, there has been an increased interest in Project Based Learning (PBL or PjBL) in STEM (Thomas 2000) relative to promoting twenty-first century skills for students. PBL environments engage students in real world activities that focus on real world problems (Krajcik and Blumenfeld 2006), often aligned with the same problem-solving skills that industry professionals implement in the workplace. The PBL environment provides an excellent platform for teaching STEM, because students are able to engage in STEM in a more authentic and applied context. Problem-solving and critical thinking skills are at the center of PBL. In this pedagogical strategy, students investigate driving questions and are allowed to propose hypotheses, collaborate with peers and discuss ideas they have regarding the problem, and test new ideas (Krajcik and Blumenfeld 2006). More specifically, research demonstrates that students who engage in PBL environments perform better on assessments than students in the more traditional classroom setting (Marx et al. 2004; Rivet and Krajcik 2004; Williams and Linn 2002). The project has been developed based on five key features of PBL (i.e., driving questions, situated inquiry, collaboration, using technology tools to support learning, and creations of artifacts) (Krajcik and Blumenfeld 2006).

Examining Attitudes, Self-Efficacy, and Motivation

Research has demonstrated that PBL integrated with STEM (especially with the integration of new technologies) can enhance students' attitudes towards STEM careers and promote meaningful learning. PBL also helps students learn to solve problems and apply what they have learned to their daily lives (Krajcik and Blumenfeld 2006). Multiple factors have been identified as contributing to participation and motivation of students from underrepresented groups in STEM (Singh et al. 2002). These factors include attitude, ability level, self-concept, socioeconomic status, family influence, home and school factors, and lack of qualified teachers (Museus et al. 2011; Singh et al. 2002). Another important factor affecting STEM participation is self-efficacy. Self-efficacy refers to an individual's belief of whether or not a task they take on can be successfully completed. Research has demonstrated that students' science achievement and self-efficacy have increased after engaging in technology-enhanced learning environments; though there was no significant change in their attitude towards science (Liu et al. 2006). Additional studies suggest that along with self-efficacy, other variables such as outcome expectations, science interest, and social support, are key predictors of persistence.

More often than not, students from underrepresented groups lack motivation in STEM because of the watered down curriculum and low expectations they encounter in the STEM classroom (Russell 2014). Similar to research in Liu et al. (2011), motivation served as a framework for this Academy. Motivational theories of self-efficacy expectations, intrinsic/interest value, and expectancy beliefs and self-concept play a critical role in the implementation of PBL. Moreover, innovative and emerging technologies are often used to create and enhance learning environments that stimulate interest in STEM. The more engaging the environment, the more students are motivated to learn the content (Gainor and Lent 1998). This Academy used the aerial drone technology applying real-world problem-solving strategies to enhance motivation in STEM. When students are motivated to engage in a challenge to complete a task or solve a problem, they are more likely to persist when they encounter a difficulty. Consequently, this innovative Academy examined students' attitudes, motivation, and self-efficacy in STEM as it relates to the implementation of the aerial drone technology in the PBL.

Design and Implementation of the Summer Academy

Maximizing student engagement in learning is one way to capture the curiosity and attention of students and use their interest or passion for a topic to enhance their academic performance to a level, which would have been difficult to obtain without the engagement taking place (Sinatra et al. 2017). In informal language, it is desirable to embed a bit of 'Wow Factor' in learning lessons in STEM subjects to capitalize on the excitement and enthusiasm by students and produce real quality learning in STEM disciplines. When students are engaged, they are more likely to perform well academically. Thus, providing a large inventory of instructional strategies is important to engage students (Garcia-Reid et al. 2005). Project Based Learning (PBL), with the aerial drone serving as the main mechanism to generate the desired 'Wow Factor', was the main focus of the STEM Summer Academy, which took place on the campus of the HBCU.

Scholar Recruitment

We recruited 30 to 60 rising 10th and rising 11th graders (Scholars) annually from high schools located in school districts of Macon and Montgomery. Each cohort was ethnically and racially diverse and also diverse in terms of gender. Over 77% of students are minority (mostly Black) in the Macon county, and about 56% students are Black in the Montgomery public schools. Detailed information about the STEM Summer Academy was disseminated to students in the form of a brochure by principals within the participating high schools. Teacher recommendations were used to make the final selections of Scholars for Academy participation. These recommendations by teachers were critical in identifying Scholars for each diverse cohort who have (a) some demonstrated inclination for STEM subjects; and, more importantly, (b) the potential to work collaboratively similar to a STEM industry setting and be able to seamlessly integrate in the Summer Academy community.

Teacher Recruitment Plan

We recruited five teachers annually from participating high schools for participation in the STEM Summer Academy. Teachers were recruited by principals from the Mathematics and Science instructional staff at participating high schools. Principals selected teachers who (a) are eager to mentor students in an informal environment; (b) are supportive of their students; (c) can be good advocates for STEM; and, (d) can be empowered to mentor other teachers on how to counsel students for STEM careers. Teachers participating in the Academy are mostly African Americans from the surrounding Montgomery and Macon counties. They participated in the Academy activities on a daily basis.

The STEM Summer Academy

The STEM Summer Academy was instituted on the campus of the HBCU in summers of 2016, 2017, and 2018 and was four weeks long. Learning took place 9 AM to 4 PM. During the daytime hours, Scholars were fully immersed in technology-rich activities alongside mentors, which included the HBCU faculty, graduate and undergraduate students from the Computer Science Department at the HBCU, and the HBCU AA representatives. During the afternoon session, Scholars worked on their e-portfolios to document their daily activities. After three weeks of Summer Academy, the students were divided into 10 groups with 3 students, 1 teacher, 1 teaching assistant, and a Computer Science faculty in each group. Each group started working on a drone application of their choice after 3 weeks.

STEM Summer Academy Activities

Comprehensive and purposeful activities were designed to illuminate pathways for Scholars for careers in STEM and provide teachers with the resources to counsel all students with the preparation needed for the STEM workforce. Below, we provide a full description of the Academy and its activities.

- **Orientation. On day one of the Academy.** Scholars and teachers received an orientation. This included a discussion of the purpose of the Academy. Scholars and teachers got acquainted with faculty and student mentors and gained an understanding of the expectations of the Academy.
- **Pre and Post-Surveys for Scholars and Teachers.** To create Scholar and teacher baseline data for the Academy, pre-surveys designed by the evaluator were administered to each of the two groups. Scholars were asked to complete surveys on: (a) Attitudes and beliefs about STEM; (b) Knowledge about careers in STEM; (c) Knowledge about the educational paths needed to enter STEM careers; and, (d) Math and Science content knowledge. Teachers were requested to take surveys focusing on: (a) Knowledge about careers in STEM; and (b) Knowledge about the educational paths needed to enter STEM careers. Analogous post-surveys were administered at the end of the Academy to assess progress over the baseline.
- **Project-Based Learning (PBL).** Early in the first week of the STEM Summer Academy, the Scholars were grouped into 10 teams of at least three students each. Each group reflected diversity in terms of race, gender, and ethnicity. Teams proposed a drone application driving question under the guidance of faculty, teachers, and the HBCU mentors. The mentors assisted each team in the investigation of their respective driving questions and to forge potential solutions. As Scholars performed their investigations, they gained precious peripheral experiences, including intellectual, scientific, technological, social and time management skills. These derived benefits are described below:
  - **Aerial Drone Assembly**. Each Scholars team was presented with an un-assembled aerial drone. Faculty and student mentors guided the students in the study of each part for proper assembly. Scholars investigated all parts and understood the purpose they serve.
  - **Hardware/Software**. As Scholars teams assembled their drones, they explored the hardware and software components along with the network of circuitry that process instructions for drone operation. Scholars also studied the interplay between them.
  - **Python Programming.** All Scholars were introduced to elementary coding in a language called "Python." Programming was done on laptop computers by each of the ten teams. The choice of the Python software is motivated by its ease of use and prevalence in the STEM industry. It comes equipped with an extensive library to support network security and data analytics applications. Moreover, it is open source. Students learned the following concepts while using Python: (a) Basic data types (integers, floats and strings); (b) Simple arithmetic and logical applications; (c) Input/output statements; Control flow; (d) If/Then, For, While loop; and (e) Sequence type: Tuple, List and String. Programs were developed by Scholars to produce different types of drone movements, process data from the drone's sensors and to configure the drone. Very simple and suggestive Python commands were used by the students to instruct the drone what to do (see Table 1 for sample set of instructions).
  - **Cloud Collaboration.** As teams worked on their driving questions, Scholars within teams (and also across teams) collaborated with each other using methods that are adopted by STEM-related workplace. To this end, Scholars were introduced to techniques such as Cloud Computing, a practice that uses a network of remote servers hosted on the Internet to store, manage and process files. For

Table 1 Elementary Python Commands for Drone Operation
drone.takeoff () # Drone starts

drone.moveForward ()	# Drone flies forward
time.sleep (2)	# ... For two seconds
drone.stop ()	# Drone stops
drone.moveBackward (1)	# Drone flies backward at 1 m/h
time.sleep (1.5)	# … for one and a half seconds
drone.stop ()	# drone stops and hovers
drone.turnLeft ()	# drone flies full speed to the left
time.sleep (2)	# …for two seconds
drone.stop ()	# drone stops
drone.land ()	# Drone lands

time.sleep (7.5) # Gives the drone time to start example, Scholars learned how to share documents through Google Drive, which is a very common practice in the STEM workplace.

- **Mini-Courses/Panels:** Short and interactive mini courses/panels were offered to Scholars to empower them about best and safe practices in the cyber world and to be responsible users of cybertechnology. Four such courses were provided: (a) Professionalism (Select Topics: Responsibility; Accountability; Teamsmanship); (b) Ethics (Select Topics: Confidentiality; Intellectual property; Stewardship of Cyberspace); (c) Security (Select Topics: Phishing; Malware; Hacking; Viruses; Encryption); and, (d) Privacy (Select Topics: Safeguard of Personal Information in Cyberspace; Invasiveness of Browsers; Cookies; Search Engines). The courses/panels were jointly offered and moderated by faculty, graduate students and the Alumni Association representatives.
- **Career Awareness (Scholars).** Throughout the Academy, Scholar teams were exposed to different STEM topics and practices as they investigated their driving questions. Associated with each STEM topic, the Alumni Association representatives counselled the students on various STEM related job opportunities that exist, including those positions that are technical in nature. Further, these representatives advised Scholars on the academic tracks they should take in high school and college to gain the necessary qualification for each STEM occupation.
- **Career Awareness (Teachers).** Studies reveal that high school is a key point where young people's impressions of Mathematics and Science influence their future career decisions (Sadler et al. 2012). It is also at this critical time that students face challenges such as a lack of clear and timely guidance in planning their careers. Schools house counselors and career specialists, but students often have limited access to these staff members, who are perhaps charged with serving hundreds of students. In such an environment, students should turn to Mathematics and Science teachers, whom they see regularly, to explore STEM-associated career options. So, it is important to empower those teachers to be able to counsel their students on STEM career options. In order to prepare the participating Academy teachers for this responsibility, the Alumni Association provided career awareness sessions for them at the Academy.
- **E-Portfolios and YouTube Videos.** Each of the ten teams of Scholars documented electronically their daily progress in the study of their respective drone-based driving questions in the form of e-portfolios. In preparation of the e-portfolio, Scholars made video recordings of their daily tasks at the Academy using their cell phones and learned how the recording is made by their devices. This gave them exposure to concepts such as pixel and resolution, color representations and frames. Scholars learned how to convert the videos in various formats and how to transfer from one medium to another along with system requirements. They also learned how to edit the video clips using editing tools.
- **Leadership Development and Teamsmanship**. As the teams of Scholars investigated their driving questions and prepared their e-portfolios bringing together all the knowledge gained during the course of the Academy, teamsmanship was critical for work efficiency, just as it is in the STEM workplace. Each Scholar team was designated a leader who delegated tasks to the other two on the team: ITEST Ambassadors and Role Models. Scholars were observed closely by the mentors throughout the Academy. Those Scholars who demonstrated leadership qualities and strong work ethics at the Academy, were considered as role models and were eligible to return to the following year's Academy as mentors alongside faculty, teacher and the Alumni Association representatives.
- **End of the year ceremony.** A culminating end-of-the-year ceremony was held at the end of the Academy. The purpose of this event was to disseminate the work of the Academy to families, friends and local community and government officials. The program was heavily focused on the Scholars who delivered five to ten minutes PowerPoint presentations about their activities at the Academy, including a presentation of their e-portfolios. The activities of the STEM Summer Academy, in the aggregate, had the potential to provide Scholars and teachers with the general scaffolding needed for STEM career awareness. A tentative timeline for the 2016 STEM Summer Academy is provided in Table 2.

Activity Details

In this section, we first describe three of the several activities that our Scholars were engaged in and then we provide a short description of the results we got through an independent evaluation process.

Hacking Analysis Competition

One of the activities that our Scholars were engaged in was a Hacking Analysis competition. A total of 300 distinct IP addresses were extracted from hacking attempts found on one of the Linux servers used in the Department of Computer Science at the HBCU. The server had been under attack since it was created for students and faculty. These IP addresses reflected some hacking attempts made to the server. The origins of the hacking attempts were from various countries in the world. This competition was designed to evaluate

Table 2 Schedule of the 2016 STEM Summer Academy

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
		June 1 •Scholar/Teacher Orientation •Administration of pre-surveys (attitudes/STEM knowledge) •Introduction to drones •Cloud Computing	**June 2** •Scholar group formation •Leadership •Cooperative learning •Delegation of tasks •Formulation of driving questions •Cloud Computing •Work on e-portfolios	**June 3** •Investigation of driving questions •Cloud computing •Drone assembly •Hardware/software •Work on e-portfolios
June 6 •Investigation of driving questions •Cloud computing •Drone assembly •Hardware/software •TEAA Career awareness sessions •Work on e-portfolios	**June 7** •Investigation of driving questions •Cloud computing •Drone assembly •Hardware/software •Python Programming •Work on e-portfolios	**June 8** •Investigation of driving questions •Cloud computing •Python Programming •Work on e-portfolios	**June 9** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 10** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios
June 14 •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios	**June 15** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 16** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 17** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 18** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios
June 20 •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios	**June 21** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 22** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 23** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •Math and Science concepts •Work on e-portfolios	**June 24** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios
June 27 •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios •Preparation for Banquet presentations	**June 28** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios •Preparation for Banquet presentations	**June 29** •Investigation of driving questions •Cloud computing •Python Programming •Drone operation •TEAA Career awareness sessions •Work on e-portfolios •Preparation for Banquet presentations	**June 30** •Investigation of driving questions •Administration of post-surveys (attitudes/STEM knowledge) •TEAA Career awareness sessions •Work on e-portfolios •Preparation for Banquet presentations	**July 1** •Work on e-portfolios •Preparation for Banquet presentations •Culminating Banquet

participants' learning outcomes and effectiveness of collaboration. They were challenged to find the top 5 countries where the hacking attempts originated, list them in the order of highest number of attempts down to the lowest, and also graph the distribution of attempts using a pie chart. The following is a detailed description of the activities involved.

- Discover the country where the hacking attempt originated
- Ally number of hacking attempts in each country
- Order the number of attempts originated from each country and select the top 5
- Create a Pie chart to illustrate the percentage of the origins of hacking attempts

Each team had to answer the following questions:

- Which country had the largest number of hackers who attempted to hack?
- What were the top 10 countries that launched hacking attempts? Display them in descending order (from highest to lowest).
- How many countries launched the hacking attempts?
- Graph the percentage of the hacking attempts.

Prior to the competition, participants had learned how to:

- Map an IP address to a city or a country using IP locator
- Tally counts based on categories in text using Google Sheets
- Order records (or rows) using keys
- Create a Pie chart in Google Sheets
- Work collaboratively with Google products in Google Drive
- Create a folder for sharing
- Share a folder with other teammates
- Edit/update files in real time
- Communicate with teammates through comments and real time chats

Raspberry Pi Experiments

A set of activities were designed based on hands-on interaction with Raspberry Pi. The participants were engaged in the following projects:

- Assemble Raspberry Pi and install Operating System
- Design a song using Sonic Pi
- Control LED lights using Raspberry Pi, circuits, and LEDs

This project was designed to provide an opportunity for the participants to assemble a small computer, identify components, make connections between the computer and peripherals, install Operating System, and configure/set up the system. Each team was given a Raspberry Pi (RPi) with a case, a microSD card, a power charger, and two heat sinks. Members of each team were responsible for

- Identifying the components of the RPi
- Adding heat sinks to the RPi
- Inserting the microSD card into the RPi
- Placing the RPi inside the case
- Connecting an HDMI cable between the monitor and the RPi
- Connecting mouse and keyboard to the RPi
- Connecting the power charger to the outlet
- Connecting the power charger to the RPi
- Installing the operating system
- Configuring the time zone, keyboard settings, and location for the RPi
- Exploring the software installed on the RPi
- Running updates and upgrades

Flying Drones Using Python

In the Academy, participants learned how to fly drones interactively through Python programs and drone APIs (Graff 2012) using pre-defined flight plans. In order to fly a drone interactively, the "pilot" must have visual access to the drone and to the drone's surrounding areas. However, to take full advantage of the drone's ability to access areas that are too far or too dangerous for live personnel to reach, a "flight plan" must be designed where the "pilot" navigates the drone to fly a specific path. In preparation for developing a flight plan using the Python programming language, participants were taught the following:

- **Basic Python Programming and Drone APIs:** This project was designed to teach participants Python programming basics, APIs for using drones (Graff 2012), Python instructions, their functions, and how to use them. Using desktop computers running on Linux server, the participants learned how to write simple Python programs.
- **Designing Python Programs to Create Different Shapes:** With the goal of having students design a "flight plan," the initial focus was on using APIs that controlled movement. Participants were guided through exercises how to draw simple shapes (i.e., lines, squares, triangles) using Motion APIs (i.e., move, turn, go to), Event (when clicked), and Control (if-then, if-then-else, wait). The use of the Cartesian plane as a background was then added to provide exact positioning in their designs.

- **Writing Python Programs to Fly Drones:** This phase of the project is where participants were taught the Python commands that can be used to control the drone. After receiving instruction on basic drone use and safety, participants were provided with a drone and taught how to connect and control their drone using Python scripts written on a laptop designated for their team. Participants worked in teams. Participants were asked to identify Python drone flying statements that were similar to the other Python statements used to design shapes in the previous phase. Simple scripts using basic drone flying instructions were provided as templates to the teams. Each team was asked to design, implement, and test at least 3 additional "flight plans" to travel a predetermined path (square or rectangle was the most commonly selected path shape). Each team comprised of a pilot (direct control of the laptop running the Python script), a flight recorder (record video of the flight for later analysis), and traffic controller (ensure drone stays in designated flight area).

Results from Project Evaluation

The Summer program was evaluated by a professor from the research university who participated as an independent evaluator of the project. For the first year, 42 students completed the Summer program, while 69 students in Year 2, and 36 students in Year 3. Majority of the participating students are African Americans (Year 1: 83.3%; Year 2: 88.5%; and Year 3: 89.8%). The details on participants are provided in Table 3. Instruments used measured the students' knowledge (15 items), attitude toward science (9 items), self-efficacy in twenty-first century skills (11 items), and interest toward STEM career (11 items). Content experts in the Summer Academy developed student content knowledge subscale. Other measures were drawn from previously validated and widely used tools, including Critical Thinking subscale from Motivated Strategies for Learning Questionnaire (Pintrich et al. 1993), and Student Attitudes Toward STEM Survey (Unfried et al. 2015).

The instruments were administrated pre and post- Summer Academy using online survey platform (Qualtrics). The internal consistency Cronbach's alpha of the measures was from 0.66 to 0.94 across three-year project period. Although a Cronbach's Alpha coefficient larger than .7 is considered satisfactory (Nunnally and Bernstein 2017), sample size is positively correlated with the value of Alpha (Abdelmoula et al. 2015; Bujang et al. 2018; Rouquette and Falissard 2011; Yurdugul 2008). With small sample size in Year 3 ($n = 27$), the alpha of the twenty-first Century Skills scale in the pre-test was the only one that had the alpha coefficient less than .70 ($\alpha = .66$). However, Nunnally and Bernstein also suggested that an Alpha value at .60–.70 is acceptable for exploratory research. In addition, some other researchers suggested that an Alpha value between .5 to .75 is considered as moderately reliable (Hinton et al. 2004). Hence, the scores received from the instruments in the current study is considered reliable.

Overall, students' knowledge statistically significantly increased after completing the Summer Academies (Year 1: $t(27) = 11.27$, $p < .001$, Cohen's $d = 3.42$; Year 2: $t(69) = 10.44$, $p < .001$, Cohen's $d = 2.27$; Year 3: $t(37) = 15.88$, $p < .001$, Cohen's $d = 2.58$). Their scores in confidence in using twenty-first century skills, attitude toward science, and their interest in STEM careers increased except the confidence in twenty-first century skills for Year 3 (See Table 4). To be more specific, students' attitude toward science scores increased statistically significantly in Year 1 ($t(27) = 2.55$, $p = .02$, Cohen's $d = 0.44$), while their scores in confidence in twenty-first century skills increased statistically significantly in Year 1 ($t(27) = 2.28$, $p = .03$, Cohen's $d = 0.32$). Their scores in STEM career interest increased statistically significantly in Year 1 ($t\ (27) = 2.14$, $p = .04$, Cohen's $d = 0.29$) and Year 2 ($t\ (49) = 2.43$, $p = .02$, Cohen's $d = 0.33$).

Discussion and Conclusion

Despite the rapidly growing availability of jobs in Information Technology (IT) and Information Security (IS) fields, minority students have not been able to take advantage of this growth. Although there is no dearth of bright minority students, their interest in STEM studies is tepid, at best. Hence there is a need for more efforts that will help develop their interest in these areas starting at the high school level. This paper has discussed one such program where both critical thinking skills and interest in STEM careers are enhanced amongst the minority students by infusing a wow factor into the project by using the aerial drone as a tool.

Based on our observations, we found that mentoring was critical for the success of the program. Throughout the project, participants had multiple opportunities to engage with HBCU mentor faculty, graduate and undergraduate students, as well as Alumni Association representatives. Students were able to share their interest and ask questions about future careers informally, and mentors shared their personal experience of working in a computer science field while guiding the project. Previous studies also have presented that mentoring support that students of color receive is critical for the success of STEM education (Palmer et al. 2011). Kendricks et al. (2013) has claimed that when students of color receive mentoring support from role models who share similar cultural backgrounds and are knowledgeable about an area of students' interest, they are more likely to be successful academically. We suggest providing appropriate mentoring support to

Table 3 Student Demographic Information

		Year 1 ($n = 32$)	Year 2 ($n = 50$)	Year 3 ($n = 29$)
School System	Macon	24 (77.4%)	26 (52.0%)	16 (55.2%)
	Montgomery	6 (19.4%)	22 (43.0%)	9 (31.0%)
	Not Specified	1 (3.2%)	2 (4.0%)	4 (13.8%)
Grade Level	10	7 (21.9%)	15 (30.0%)	9 (31.0%)
	11	14 (43.8%)	19 (38.0%)	12 (41.4%)
	12	11 (34.4%)	16 (32.0%)	8 (27.6%)
Sex	Female	16 (57.1%)	28 (56.0%)	14 (48.3%)
	Male	12 (42.9%)	22 (44.0%)	14 (48.3%)
	Prefer Not to Answer	0 (0.0%)	0 (0.0%)	1 (3.4%)
Race	American Indian/Alaska Native	3 (10%)	2 (3.85%)	0 (0.0%)
	Asian/Pacific Islander	0 (0.0%)	0 (0.0%)	0 (0.0%)
	African American	25 (83.3%)	46 (88.5%)	26 (89.8%)
	White	0 (0.0%)	4 (7.7%)	1 (3.4%)
	Other	2 (6.7%)	0 (0.0%)	2 (6.9%)
	Prefer Not to Answer	0 (0.0%)	0 (0.0%)	0 (0.0%)
Hispanic Origin		1 (3.6%)	1 (2.0%)	2 (6.9%)
Disability		1 (3.6%)	2 (4.0%)	0 (0.0%)

Note: percentages are based on responding cases

promote minority high school students' interest and engagement in STEM learning.

Another factor affecting positive outcomes of this project was the provision of challenging and yet engaging engineering problems. We provided real life problems that students need to solve by applying programing skills and cybersecurity knowledge in a collaborative environment. The formative evaluation results indicated that challenging activities helped students be creative, engaging, and innovative, and participants' successful experiences helped promote students' self-efficacy. The incorporation of aerial drones also boosted students' curiosity and engagement. None of participants had ever used a drone before, and learning to fly a drone was a challenging yet captivating experience. Each team member had a specific role to perform and had to work together to accomplish a given task. During this process, students needed to share ideas and feedback among team members as well as with other teams. A study by Chen et al. (2015) found that peer discussion was one of the essential components influencing Hispanic students' active participation in a computer networking class. Participants, mostly African American, in this study enjoyed the social learning environments as well; further research is needed to examine whether social learning environment positively influences African American students' STEM learning.

The four-week duration appeared to positively influence students' learning. The provision of over 100 intensive hours allowed students to learn new skills and knowledge and apply them to an authentic problem solving situation. Other studies also reported the benefits of longer project hours. For instance,

Table 4 Student Score Comparison across Three Summer Academy

Subscales	Year 1 ($n = 28$)			Year 2 ($n = 50 \sim 70$)			Year 3 ($n = 27 \sim 38$)		
	Pre *3*	Post *M (SD)*	Effect size Cohen's *d*	Pre *M (SD)*	Post *M (SD)*	Effect size Cohen's *d*	Pre *M (SD)*	Post *M (SD)*	Effect size Cohen's *d*
STEM Knowledge	7.68 (2.15)	13.57 (1.14)	3.42 ***	7.22 (2.10)	10.66 (1.70)	2.27***	5.32 (2.29)	11.84 (1.26)	2.58***
Attitude toward Science	3.55 (0.96)	3.94 (0.83)	0.44*	3.47 (0.69)	3.63 (0.83)	0.27	3.63 (0.82)	3.85 (0.77)	0.33
Confidence in twenty-first Century Skills	4.53 (0.62)	4.70 (0.43)	0.32*	4.47 (0.44)	4.52 (0.63)	0.11	4.66 (0.24)	4.65 (0.35)	−0.04
STEM Career Interest	4.07 (0.65)	4.26 (0.66)	0.29*	4.01 (0.55)	4.15 (0.56)	0.33*	4.13 (0.66)	4.25 (0.72)	0.22

Note: ***p < .001, ** $p < .01$, * $p < .05$

Nugent et al. (2010) provided robotics and geospatial technologies interventions to middle school students and reported that the 40-h intensive group demonstrated significantly greater learning than the control group that did not receive any training. The 3-h short term intervention group did not present a significant learning gain but presented positive attitude towards STEM. Based on our finding, we suggest offering a longer duration experience to students in order to foster students' STEM knowledge and skill development as well as increased interest and positive attitude towards STEM-related careers.

Although the implementation of the drone project was successful, we felt that the Scholars should experience a fun-filled application before they start using a traditional programming language such as Python. We are proposing to use App Inventor with Android smartphones for a similar project in the future. App Inventor is a Cloud-based open source software developed by MIT and Google based on a visual blocks-based programming language. Topics to be explored by scholars will include: (a) Data types, Variables and Expression; (b) Conditional Variables and Loops; (c) Procedures, Event, and Event Handler; and 4) Database and Web Services. Regarding future research, we plan to conduct more qualitative research to explore both students and teachers' experiences. To do so, we plan to conduct focus group and individual interviews with participants and examine various positive and negative factors affecting participants' Academy experiences and future career decisions. We are particularly interested in identifying appropriate ways to support teachers, so that they can implement a similar project in their own classroom to broaden participation of minority students in STEM.

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Compliance with Ethical Standards

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Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Tuskegee University Human participant Review Committee, Institutional Review Board-IRB # **00001137** + reference number **HPRC #110915**) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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