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Exposing Middle and High School Students to the Breadth of Computer Science

Dr. Daryl Bryant Stone, Bowie State University

Dr. Daryl Stone successfully defended his Doctoral Dissertation, titled "African-American Males in Computer Science – Examining the Pipeline for Clogs", at George Washington University. His goal is to find ways to recruit, prepare and retain more minorities in the Science, Technology, Engineering and Mathematics (STEM) areas, specifically, the Computing Discipline.

He is currently an Assistant Professor in Bowie State Universities Computer Science Department. Dr. Stone is the Founding Director of the CPU Camp (Computer Programming for Youth). CPU Camp introduces the basics of computer programming and College to Middle and High School Students. Additionally, Dr. Stone teaches courses in the area of Internet Programming, Oracle Database Development and Programming in C/C++.

Dr. Quincy Brown, Bowie State University

Dr. Quincy Brown is an Assistant Professor in the Computer Department at Bowie State University. She is a 2009 recipient of the National Science Foundation/Computing Community Consortium CI Fellows Postdoctoral Research Fellowship award. She completed her doctoral work at Drexel University where she was a National Science Foundation GK-12 and Bridge To the Doctorate Fellow. As a GK-12 Fellow she taught and developed STEM curricula for middle school students. Through her research she seeks to identify methods of facilitating human interaction with advanced technologies, including mobile devices, to support learning. Specifically, her ongoing projects examine the design of intelligent tutoring systems, delivered on mobile devices, to support middle school mathematics learning and exploring the design and usability aspects of mobile device use by children.

Generation Innovation: Exposing Middle and High School Students to the Breadth of Computer Science

ABSTRACT
In this paper, we describe our experience running Generation Innovation, a camp for middle and high school students. For five summers we have hosted Generation Innovation with the primary goal of exposing students to the breadth of topics in computer science. Most computer camps focus on one topic for the duration of the program. During our camp, we engage students in activities related to multiple computer science topics, such as robotics, mobile applications, and HTML. Nearly 200 middle and high school students, 97% of whom are African American, have participated in our program. In this paper we describe Generation Innovation activities and the evaluation of the program. Post-camp surveys revealed that participation in Generation Innovation leads campers to better understand the breadth of opportunities available in the computer science discipline.

1. INTRODUCTION

Generation Innovation is a computer science education summer camp for middle and high school students. The camp began in 2009 as a male-only program. In 2011, it was expanded to provide CS education to both girls and boys. The camp is held at Bowie State University, a historically black college, and is focused on providing low cost CS education activities to students in the local area. This paper summarizes our efforts and presents the results from five years of conducting the program.

The mission of Generation Innovation is to introduce middle and high school students to the breadth of areas within computer science. Through this program, we aim to dispel the myth that computer science is focused only on programming. Students experience, first hand, the variety of activities and career paths within the discipline. Through exposure to multiple topics, we provide participants with an opportunity to discover the aspects of computing that is of most interest to them. The goals of the summer camp are to:

- *Expose students to the breadth topics within computer science*
- *Provide a low-cost summer program*
- *Expose students to role models who "look like them"(The program is open to all, but targets underrepresented members of Computer Science arena)*
- *Provide students with technical skills*

We expose students to a variety of topics that fall under the computer science "umbrella". These topics include: robotics, HTML, mobile application development, and 3D printing. In addition to the hands-on technical skill development, we provide students with opportunities to experience life on a university campus. To that end, STEM and computing professionals talk to students about their background, career paths, and career interests. Additionally, students interact daily with role models who "look like them", and are African American undergraduate and graduate students who work as camp staff. Though our program has primarily served African American students, we believe that students from all ethnic, gender, and socio-economic groups benefit from the inclusion of staff who "*look like them*". In addition to the technical skill building we provide participants with tours of our university campus.

2. RELATED WORK

To understand the topics covered in similar K-12 summer outreach camps, we surveyed the Internet and conducted a literature review. We found that the majority of programs are single themed and focus on one aspect of computer science. For example, most camps offer one-week sessions on one of the following topics: game development, mobile app development, robotics or focus on STEM, in general, with emphasis on engineering.

Georgia Tech's Institute for Computing Education Summer Camp offerings consists of one week camps that cover topics such as Scratch, Robotics, Mobile App Development, and Alice[11]. Similar camps at the University of Maryland College Park engage students in STEM activities, but do not explicitly focus on computer science or computing [5]. Likewise, non-profit organizations such as Tech Corps hosts camps throughout the United States. Tech Corps offers one week camps that cover single topics such as mobile app development, programming, robotics, and web development[10].

3. Generation Innovation Description

Generation Innovation is a camp developed to increase the number of underrepresented minorities in the Computer Science pipeline. The camp fills the eminent need to provide STEM training to middle and high school students and their families. The Generation Innovation camp brings two single-gender programs, CPU Camp for African American Males and Girls Who Will, together into one cohesive program. The two programs are run in parallel and engage students in similar activities throughout the two weeks. The male and female participants perform technical skill building activities separately. However, the students from both programs come together to listen to speakers, eat lunch, and showcase their acquired skills at the Closing Ceremony.

Though we advertise broadly, the program targets African American participants. Additionally, the surrounding county is comprised primarily of African-Americans. Therefore, ninety-seven percent of the participants have been African American. Since 2009, 110 African American males have completed the CPU Camp for African American Males. Since 2011, 65 females, 61 of whom are African American, have participated in the Girls Who Will summer camp. The participants are recruited through advertising on the CS Department website, email to the local county school districts, previous participants, and word of mouth. Each year we aim to have no more than 60 attendees: 15 middle and high school students of each gender. Our goal is to maintain a ratio of no more than 1 staff person per 5 attendees. Parents or Guardians must complete an online application that includes: demographic information, a copy of the student's most recent report card, a statement describing the participants' interest in computing, and a recommendation form submitted by a teacher.

Comparatively speaking, the cost of our camp is relatively low. While our fee is just $225 for two-weeks, most camps charge close to that same amount for one week[4, 5, 11]. The greatest financial expense associated with hosting our camp is the cost of paying for university student staff. Students bring lunch, except for the last day, when the camp directors purchase pizza for the camp. We do provide a daily snack. Other costs include cost of logo'd items, e.g. cups and lanyards, which are given to each camper at the Closing Ceremony. Additional expenses include moderate equipment replacement costs, such as replacing mobile devices and small Lego pieces or consumable supplies such as puffy paint and glue.

3.1 Camp Activities

During each two-week camp, students engage in computing projects such as implementing digital games using Scratch, creating mobile applications using App Inventor, engaging in robotics activities, cybersecurity, and using Arduino electronics to explore wearable computing. Additionally, students learn HTML and maintain a website detailing their camp activities. To maximize the number of topics covered during the 2-week period, we coordinate the sharing of needed items, as shown in table 1. Each summer session concludes with a Computing Showcase where participants demonstrate their accomplishments to their families, friends and invited community members.

Here we describe the activities that have been implemented throughout the years of Generation Innovation. It should be noted that not every activity is implemented each year. To ensure we provide programming that will engage attendees, the specific schedule varies based on the number participants and whether attendees have participated in previous iterations of the camp.

	Week 1	Week 2
Monday	Introduction, HTML	Game Design
Tuesday	Robotics	Game Design, Mobile Apps
Wednesday	Robotics, Speaker	3D Printing, Wearable Computing
Thursday	Cybersecurity	Wearable Computing
Friday	Cybersecurity	Wrap up, Closing Ceremony

Table 1 Sample Schedule

3.1.1 Technical Skill Development

3.1.1.1 Mobile Application Development

The introduction of visual programming environments for mobile app development such as App Inventor[7] has enabled novice programmers to design and implement mobile applications with little programming expertise. We introduce students to mobile app development using App Inventor as a means of demonstrating that computing is accessible. Students create technology that they design and can use in their everyday lives. Completed projects include xylophone, pet shelter locator, and a set of nails, hair, and clothing design instructions. A few examples are shown in figure 2.

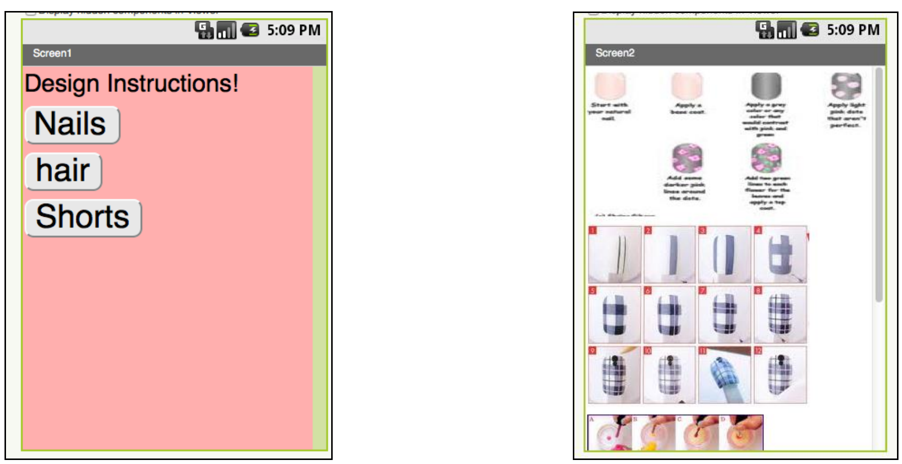


Figure 2 Nail, hair, and clothing design mobile app created by participant

3.1.1.2 Digital Game Design

The availability of visual programming environments, such as Scratch and Alice, has contributed to the popularity of game design as a theme for computing camps[1]. The majority of participants enjoy playing video games and we include the game design activities to provide students with an opportunity to understand how games are designed. Game design activities also provide an opportunity for participants to explore their creative side and make their own games. In our camp, we have conducted game design activities using Scratch[9] and Game Salad[3]. Participants have made games with themes around healthy eating, hanging out with friends, and Halloween.

3.1.1.3 Cybersecurity

Bowie State University is home to a NASA satellite operations center. Participants tour the center and learn about the role of communication and scientific principles that enable satellites to orbit the earth. They are also taught about the transmission protocols and computing methods enabling data transmission, as well as associated security issues. Through the cybersecurity activities, participants are introduced to topics including online safety, data encryption, and hacking. Specific examples of activities include student creation of cipher wheels and using them to encrypt and decrypt a message, shown in figure 3. Participants used role-playing to create a skit focused on online security. In the skit, they taught peers about creating safe passwords, cyber bullying, and the importance of being careful when sharing personal information online.

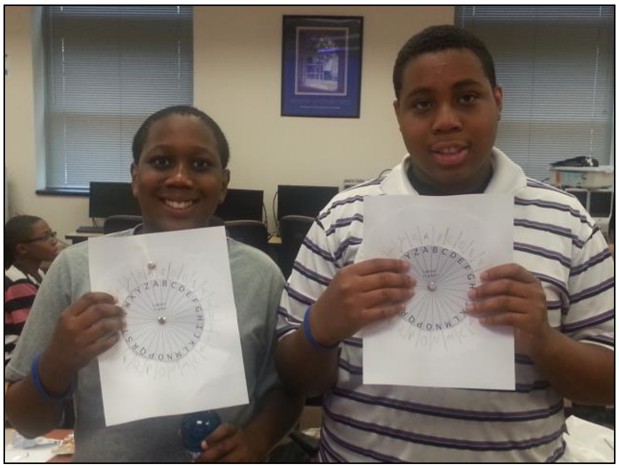


Figure 3 GI participants displaying completed cipher wheels

3.1.1.4 3D Printing

Since the advent of the first 3D printer in the 1980s, 3D printing has seen large growth in the 21st century. 3D printing has primarily been used for visualizing and communicating early product designs in fields such as in dental industries, architecture, and automotive design. However the availability of low cost desktop 3D printers has given rise to the use of 3D printers with DIY enthusiasts and educators. We use 3D printing activities to provide students with a computing activity that would yield a tangible artifact. 3D printing activities begin with students using CAD software to design a 3D object. Once their designs are complete the designs are printed using a single color 3D printer with PLA plastic[8]. Students created individual projects such as rings and key chains as well as larger group projects such as a car.

3.1.1.5 Robotics

The use of Lego NXT robots is common in many K-12 outreach programs[6]. Similar to those camps, we engage students in robotics activities. Campers are tasked with assembling a robot from the kit of parts and then programming the robot to complete specific tasks such as following a line on the ground or exhibiting a specific behavior when the color red is sensed. Once campers have an understanding of how to assemble and program the robots, we set up a series of design challenges. For each challenge, campers are tasked with designing a robot to meet specific criteria. We then evaluate the robots, using the criteria. The highest rated robot creators are awarded small prizes, such as headphones and t-shirts.

3.1.1.6 Wearable Computing

We use sewable electronic components from the Arduino LilyPad product suite[2] including programmable microcontroller boards, LEDs, buzzers, and switches. Using the components and conductive thread participants completed projects that use computing and textiles. In addition to the circuit components, participants were also provided with puffy paint, markers, feathers, flowers, beads, and other arts and crafts supplies. They were able combine materials and textiles, e.g. t-shirts, tote bags, to design light up tote bags, figure 4, t-shirts, skirts, and plush stuffed animals.

Figure 4 Tote bag with Arduino TinyLily and LEDs

3.1.2 Computing Career Awareness

Throughout the two-weeks, we discuss computer science related careers with participants. In addition to the inclusion of near-peers, we invite African-American computing and STEM professionals from industry, government, and academia. The professionals meet with participants, share their life experiences, current jobs and career paths. Campers are very interested when they hear about the speaker's childhood experiences and K-12 education. Prior to their visits, we tell the students about the visitor and help them to think of questions they would like to ask.

3.1.3 College Life Experience

In addition to the technical skill development, we provide students with an opportunity to interact with camp staff who act as near-peers who "*look like me*". We hire Bowie State University undergraduate and graduate students as camp staff. The girls' camp is staffed with African American female students and the boys' camp is staffed with African American male students. This structure enables us to provide participants with an opportunity to learn about college life from current college students. In addition to the use of near-peers, participants take tours of the campus and academic buildings to see the campus first-hand. Each summer, students are introduced to campus administrators including department chairs, college deans, and even the University President. These administrators offer words of encouragement as well.

3.1.4 Computing Showcase

On the last day of each camp, we host a computing showcase to allow participants the opportunity to share their acquired skills, with their friends and family. We extend the invitation to department faculty, the campers' family, and friends. The last morning of the camp is spent preparing for the showcase.

4. EVALUATION

Though in existence since 2009, we did not formally collect summative assessment data until 2013. Our previous efforts were focused on collecting formative assessment data that enabled us to understand the experiences of the participants and their parents. Those data were used to revise the structure of the program with respect to implementing an online application system, reducing the number of students per session, and identifying topics and activities that students enjoyed. Our recent summative assessment efforts focus on the impact of our program on the students and their access to and experiences in computing. Here we report on data from the 2013 iteration of the GI program.

4.1 Survey Results

Pre-camp and post-camp surveys were used to examine the impact of the camp. In both surveys, campers were asked to answer questions to measure computer science self-efficacy and to evaluate their opinions of computer science careers. Computer self-efficacy questions required the campers to rate, on a seven-point likert scale (1 – strongly disagree, 7 – strongly agree), statements such as, "If I get stuck on the computer, I can get it working again " and "I find working with computers very easy". To gage their thoughts on computer science careers we asked questions such as "Would you want a career in computer science?" and "What does a typical computer scientist look like?". Here, we report on campers' understanding of computer science careers.

4.1.1 Demographics

In 2013, thirty campers participated in Generation Innovation. Of the thirteen females and seventeen males, twenty-eight were African-American. There was one Caucasian/White and one American Indian/Alaskan Native camper. There were sixteen high school and fourteen middle school campers. Of the thirty campers, only twenty-three completed the pre and post-test surveys. The other seven campers missed either the pre or post-test surveys due to personal scheduling conflicts.

4.1.2 Quantitative Results

4.1.2.1 Computer Self-Efficacy

On the pre and post survey, participants were asked to rate their agreement with the statement: "*I find working with computers very easy*". On the seven-point likert scale, one was "strongly disagree", four is neutral, and seven is "strongly agree". Analysis by gender revealed that the participants' rating of their ease of computer use was high on the pre- and post- surveys (male pre M=5.80, SD=1.37, post M=5.67, SD=1.67 and female M=4.88, SD=1.61, post=5.44, SD=1.23). However, t-test analysis revealed that the female participants reported a significant improvement in their feelings that computers were easy to use ($p<0.05$) after their participation in GI while the male scores did not significantly change ($p>0.05$).

We also asked participants to use the same rating scale to indicate their agreement with the statement "*I seem to have difficulties most of the times I use the computer*". Analysis by gender revealed that while the male participants did not did not significantly change their level of agreement pre- (M=2.87, SD=2.09) to post- (M=2.60, SD=2.16) survey, the female participants experienced a marginally significant ($.05<p<.10$) improvement in their pre- (M= 4.74, SD=2.44) to post- (M= 2.34, SD=1.22) survey indications of their perceived level of difficulty while using a computer. Analysis also revealed gender differences with the agreement with the statement "If I get stuck on the computer, I can get it working again". Male participants did not exhibit a difference in their pre- (M=4.73, SD=2.01) and post- (M=4.73, SD=1.86) survey responses while the female participants exhibited a statistically significant ($p<.05$) increase pre- (M=3.25, SD=2.12) to post- (M=4.56, SD=1.42) survey responses indicating an increase in their perceived ability to use computers.

4.1.2.2 Perception of CS Difficulty

On the pre-and post- survey, paricipants were asked to rate their agreement with the statement: "Studying Computer Science is hard”. On the seven-point likert scale, one was “strongly disagree”, four is neutral, and seven is “strongly agree”.

Anaylsis revealed that male (M=3.30, SD=1.54) and female (M=3.22, SD=2.16) campers thought that studying CS was not that difficult. However, post-camp survey analysis revealed that upon completion of the the two-week program female participants exhibited positive movement in their level of disagreement (M = 2.77, SD=1.78) while their male counterparts exhibited negative movement in their level of disagreement (M=4.53, SD=1.45) with the negatively worded statement. This comparson indicates that though both groups had similar perceptions at the beginning of camp, males perceived CS to be more difficult after camp than did the female campers. This result is consistant with previous research indicating that males have a greater confidence their self-efficacy than do females[12]. In future iterations of the camp we will include additional survey questions to better understand this result.

Table 4 Studying CS is hard - Females

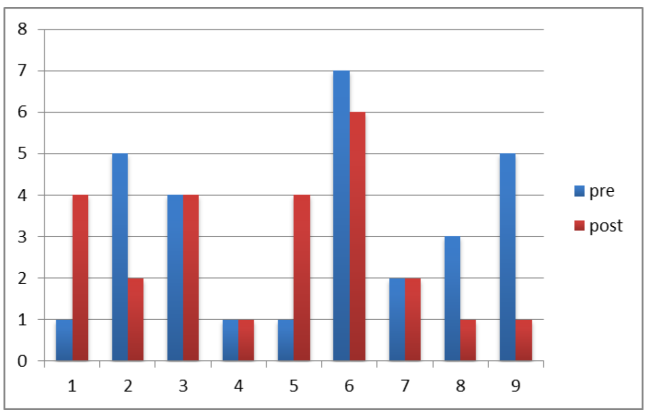
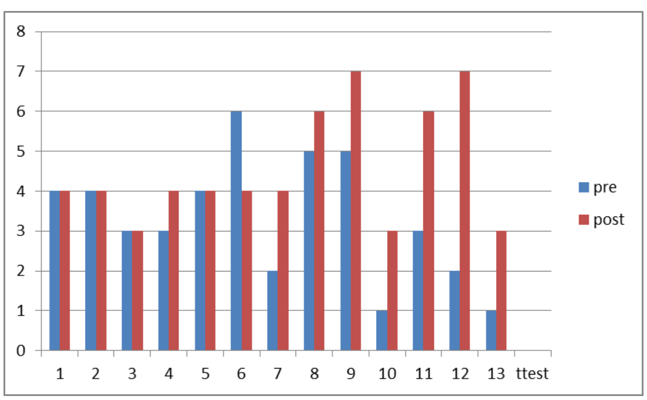


Table 5 Studying CS is hard – Males



4.1.3 Qualitative Results

The campers’ responses to questions concerning careers in computing provided qualitative results. The following presents an analysis of three such questions.

4.1.3.1 "How do you define a computer science?"

We found that most of the campers had difficulty defining computer science on the pre-camp survey and most of the campers defined CS as "the science of computers". However, on the post-camp survey their definitions were more detailed. In these responses some of the campers listed areas within CS, such as programmers, network engineers, and cyber-security specialists.

4.1.3.2 "What does a computer scientist look like?"

When asked "What does a computer scientist look like?", the female participants answers included "*a normal person*", "*average person*", "*any person walking down the street*" and "*any person, as people come in various shapes and sizes*". Male participants responses included "*a normal guy*", "*a guy with glasses and sweater vest*", "*a nice dress guy*", and "*a normal person but likes to use electronics and uses the computer a lot if you asked if he did.*"

Though participant responses revealed that most campers did not describe stereotypical computer science images we did note that responses from female campers were gender neutral while many of the male responses included the pronoun guy. We also noted that none of the participants mentioned race, age or the word "nerd".

4.1.3.3 Understanding the Breadth of Computer Science

Our analysis revealed that after participating in our camp students better understood the breadth of opportunities available in computer science. For example, when asked "What kind of jobs are there in Computer Science?" on the pre- and post- camp survey one participant responded "*There are jobs such as engineers, tech support, professors in computer science, and technology or media teachers in school.*" on the pre-camp survey and "*There are like a million different jobs in computer science and I can't really name all of them but some examples would be Jobs*[sic] *in cyber security, engineers, and technicians.*" on the post-camp survey.

The change in answer highlights why we believe that exposing students to multiple aspects of computer science will deepen their understanding of the field. We recognize that given the cost of many camps, approximately $300 each week, the possibility of a student enrolling in multiple camps to gain exposure to more than one aspect of computer science may be more than many families can afford.

4.2 Lessons Learned

Over the five years of running GI we have learned a number of lessons that we present here for others interested in hosting similar programs for reference.

Tailor specific curricula to student interest. In earlier iterations of *GI* we aimed to provide identical activities to campers in the CPU Camp (CPU) and Girls Who Will (GWW). Though we do not believe that there should be gender specific activities as a means of excluding either group from an aspect of CS, we have learned to be flexible with the amount of time spent on each activity type. For example, after completing one and a half days of robotics, the GWW participants were satisfied and ready to transition to the next activity, whereas the CPU campers wanted to spend the complete two days doing robotics. Therefore, the GWW staff had unexpected unplanned time.

Avoid "drop ins". We had camp participants who have had visiting relatives during the camp session. We have been asked, more than once, if a camper's relative, e.g. cousin or sibling, can attend camp for one or two days. Initially we accommodated the request, however we realized that the introduction of a new camper for one or two days was difficult for the campers and staff. We also learned that this is a liability for the university.

Share equipment to minimize expenses. One of the ways in which we are able to keep the cost of our camp lower than most is by sharing resources between CPU and GWW . Though we provide the same technical skill building activities to the male and female campers, we do stagger the order in which they experience them. This allows us to use fewer pieces of hardware for both camps than if we were conducting all activities simultaneously. For example, we purchased 20 Lego NXT kits and do not have enough for each student to use their own kit. However, by staggering the order of activities we can provide each group (high school girls, middle school girls, high school boys, middle school boys) with the set of 20 for up to two days each.

Offer reduced camp fees. We have intentionally priced our camp fee, $225 for two-weeks, to be much lower than that of similar camps in the area. However, we do encounter prospective campers who cannot afford our camp.

Plan down time. In the earlier iterations of *GI* we were narrowly focused on providing campers with exposure to as many areas of computer science that we could within the two-week timeframe. However, we quickly realized that campers became overwhelmed and did not like being indoors or in front of a computer all day. We now include down time for campers to engage in activities such as playing basketball and video games. We have found that during this down time we are able to build relationships with campers that allow us to discuss more than computer science and serve to strengthen the mentoring/role model aspect of our camp. We have also found that during these times campers build relationships with one another and discover similar interests or hobbies. It is not uncommon for camp participants to become Facebook friends or being to follow one another on Twitter, or similar sites, and maintain those relationships once camp is over.

5. CONCLUSIONS AND FUTURE WORK

From 2009-2013 we have successfully offered the Generation Innovation (GI) camp to nearly 200 students and overall the 2013 iteration of GI was a success. We were able to provide computer science education activities to thirty middle and high school students. The goals of the camp were to expose students to the breadth of computer science by providing a low cost camp that is staffed with near-peer role models. Furthermore, the combination of including multiple activities at a low cost enables students to find their place in computer science, i.e. an area of interest to them, and further dispelling the myth that computer science is all about writing software. Though we have targeted African American students, we believe that our program structure can be implemented for students from all ethic and socio-economic groups. Though we have offered the program since 2009, we have presented data from 2013 only. In future offerings we will continue to collect data regarding student and parent backgrounds, e.g. whether they would be first generation college students or parental occupation, students' participation in the program, their self-efficacy, and their educational progress after completing our program. Anecdotally, from participants sending informal email messages, we do know that two of the male participants are currently majoring in computer-related fields in college. Future work will also include follow up surveys with previous participants to better understand the long-term impact of their participation on choice of major in college and coursework in high school. In the future, we would like to expand our camp and include school year workshops for camp parents and campers to keep them engaged in computing activities. Given our success with students in grades 6-12 we also intend to introduce a camp to students in grades 1-5.

6. ACKNOWLEDGMENTS

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