Impact of a Year-round Out-of-School Maker Program on Minority Middle School Boys (Work in Progress)

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Introduction

African-Americans, Hispanics, and women are underrepresented in science, technology, engineering and mathematics (STEM) disciplines. As shown in Table 1, for the African-African population, which is the focus of this paper, males are 5.6% of the population but only 2.9% of the engineering workforce while females are 6.4% of the population and 0.7% of the engineering workforce, although they are 3.6% of the workforce when science and engineering are considered. In contrast, White and Asian men are overrepresented in engineering. Due to the significant underrepresentation of white, black and Hispanic women in engineering, a number of National organizations and initiatives provide extra-curricular opportunities to expose girls to engineering and computer programming [1]–[3]. While some academics and organizations are working on the underrepresentation of minority males in STEM, few National engineering and computing programs targeted at minority males in middle school were available at the conception of this effort in 2014. Partnering with Minority serving institutions, The Verizon Foundation has funded 12 programs to address the gap in engineering and computing programs for low-income minority males in grades 6 - 8, living in urban and rural areas. This paper provides preliminary results from the first year of the program at a single institution.

Table 1: 2014 US Population and Employment Statistics in Science and Engineering (S&E), by gender and race (NSF, 2015) [4]

	Female population	Female S&E	Female Engineering	Male population	Male S&E	Male Engineering
White	33.3%	32.9%	10.3%	31.8%	39.7%	63.5%
Asian	2.9%	4.8%	2.3%	2.5%	6.6%	11.8%
Black or African American	6.4%	3.6%	0.7%	5.6%	2.7%	2.9%
Hispanic or Latino	7.6%	3.8%	1.1%	7.7%	3.8%	5.5%
Other minorities	1.2%	1.1%	0.3%	1.1%	1.0%	1.5%

Program Overview

The program, initially funded through the Verizon Innovative Learning (VIL) Program (VILP) for Minority Males for two-years, is designed to introduce middle school males and their teachers to 3D modeling and mobile application development. The program also integrates ethnically-matched mentoring and entrepreneurship. This VILP is situated at Morgan State University (MSU or Morgan), a Historically Black College/University (HBCU) where 85% of the enrolled students are African-American. The program is located in Baltimore City, which is predominantly African-American and whose public school students comprise the main source of participants for the program. During the 2015 – 2016 pilot program, participants attended a four-week summer program in July, and 10 Saturday sessions from October to May. The summer curriculum was developed and delivered by University faculty from the Departments of Electrical/Computer Engineering, Civil Engineering, Mathematics, and Computer Science, and the Entrepreneurship Development and Assistance Center. The Saturday program was developed by faculty and delivered by faculty, alumni and students. Participants were identified via a partnership between the University and Baltimore City Schools Office of College and Career Readiness. Four schools were initially selected based on delivering the Gateway to Technology curriculum from Project Lead the Way, student demographics, and proximity to the University. Working through Principals and contacts from other after-school programs, additional public schools were contacted, to meet enrollment targets.

Program Implementation

Thirty-eight students participated in the VILP based on the following criteria: 1) enrolled in a public school within about three miles of the University, 2) 5^{th} – 8^{th} grader in the 2014 – 2015 academic year, and 3) willing to attend at least three weeks of the program. Ten schools were represented in the VILP with an even split between traditional and charter schools (almost 25% of City Schools are non-traditional), with 65% - 95% of students receiving free and reduced meals, a measure of low socioeconomic status for families. Participants received instruction in 3D modeling, mobile application development, mathematics and entrepreneurship interspersed with other activities such as robotics, field trips, and games. Software tools were chosen so that participants were able to use them off-campus, if they had access to a computer and the Internet. Many participants took advantage of this option. The program integrated experiential learning theory [5], 21^{st} Century skills such as creativity and technology proficiency [6]–[8] and ethnically matched mentorship [9], [10] to increase academic success, self-efficacy and a sense of belonging in STEM. Where possible, instruction and activities were aligned with the Next Generation Science Standards for engineering and Common Core Mathematical practices. In addition, near-peer mentoring was provided by undergraduate and graduate students in related disciplines.

Summer Program

The components of the four week summer program are described below:

- 3D Modeling: Participants were introduced to visualization in three dimensions, geometry, isometric drawing, extrusion, slicing and meshing using Autodesk's TinkerCAD. They were guided in the design of keychains, a ruler, one chess piece, sunglasses, headphones, and video game controller. After instructor certification of required tasks, participants could create independent products such as personalized mugs for family members and 3D models of their art work. Some of these products were printed and taken home.
- Application Development: Participants developed seven Android apps using examples from the MIT App Inventor website and the instructor. They were introduced to the block editor, image sprites, timers, text blocks, clock, sound, random numbers, event handler, list variables, mathematical formulas, procedures, and using a database.
- Mathematics: Mathematics instruction was designed to reduce loss in proficiency during the summer and support the 3D modeling and app development curriculum. Topics included geometry, mathematics tricks and shortcuts, division, exponents, square roots and logic.
- Entrepreneurship: Participants were introduced to entrepreneurial ventures through topics like marketing, financing, business models and visits from local technology entrepreneurs.
- Final Project: In the fourth week, participant teams were asked to develop an entrepreneurial venture. The teams brainstormed and refined a concept that integrated an app, a 3D model, business plan and a website or social media page. Ventures ideated were a) Customized key chain with GPS locator, b) Online comparison shopper, c) Healthy recipes creator from list of ingredients, d) Food delivery in local neighborhoods, e) Financial literacy for kids, and f) K-12 learning helper. They presented their ideas to parents at the closing ceremony.
- Other Activities: Off-campus field trips provided opportunities for participants to understand engineering in a different context. Students also interacted with African-American, primarily males, in technology who had national prominence (in-person or via video conference).

All instructors for the program were experts in their field and were full-time faculty or staff at Morgan. The instructors were responsible for designing the content and provided the topics to be covered, learning objectives and outcomes or products for each session. In order to ensure a

positive learning environment, STEM undergraduate and graduate students served as classroom assistants and mentors to program participants. In the summer, the mentors were on campus for two weeks before participants arrived, to learn how to use software tools and create a PowerPoint deck (with reflection questions) about black and Hispanic inventors. The mentors also learned about behavior characteristics of middle school boys and how to create a supportive interaction. They also received training from CARES Mentoring Movement, an organization dedicated to healing African-American communities through mentoring.

Academic Year Program

During the academic year, activities were converted from semester-long to session-long during the Saturday program since participation dropped by about 50% (due to sports and other commitments) and attendance was not as regular. Some sessions were themed with National events such as Engineers Week and Arduino Day. For example, participants created a robot from an Arduino processor, learn about ciphers and how to edit videos. The 3D modeling instruction and activities continued but app development was extended to include other programming languages. There was no separate mathematics instruction, instead, it was integrated with other topics. Example 3D design activities include designing a bus shelter after reviewing guidelines from a local Department of Transportation, and using geometry principles such as translation and reflection to design a helicopter. Participants also received instruction in user interface design for Android apps. Engineering students served as classroom assistants and program mentors.

Preliminary Results

The program was externally evaluated based on participant surveys and six observational visits to Morgan during the summer program and academic year. The evaluation team developed a survey that was grade-appropriate and observed program implementation. Surveys were designed to address the Research Question: To what extent does participation in the MMM Program increase students' 1) attitude about STEM, 2) content knowledge, 3) interest in STEM, 4) interest in STEM careers, and 5) interest in attending college? The survey was administered at the start of the summer program (*July 2015 pre-test*), at the end of the summer program, and at the beginning (*October 15, post-test*) and end of each semester (*May 2016 post-test*), during the academic year. Surveys were initially designed to be anonymous (*38 students*), but were later modified to provide a unique identifier that allowed for longitudinal tracking of those who returned during the academic year (*12 students*). The following survey questions and prompts were used to address the research questions using one of three scales (*A: very=1, ok = 2, not = 3; B: Strongly Agree = 1, Agree = 2, Neither = 3, Disagree = 4, Strongly Disagree = 5; C: very = 1, moderate = 2, some = 3, little = 4, not = 5*). Data analysis is preliminary and ongoing, and the results below represent a work in progress, and thus highlight the most significant findings.

1) Attitude about STEM: *How good are you at math?*[A] *How good are you at science?*[A] As shown in Figure 1, student perceptions of their aptitude for science remained high for about three months after the summer program, but fell by the end of the academic year. Unfortunately, attitudes about mathematics fell after the summer program. An open ended question, *I like to imagine creating…* showed that in 2015 the top three creations were related to business ventures (22%), apps or games (25%) and non-computing/engineering ideas (31%). By 2016, the top three were business ventures (18%), engineering ideas like phones (18%) and 3D design applications (27%). *S*urvey questions about attitude not discussed: *Please fill in the circle that best describes your response:*[B] *I am good at problem solving. I like to solve problems by myself. I like to solve problems in a*

group. I can see how math is important in my life. I like to imagine creating new products. I would like to start my own business. I like technology. I enjoy Math. Science is one of my favorite subjects.

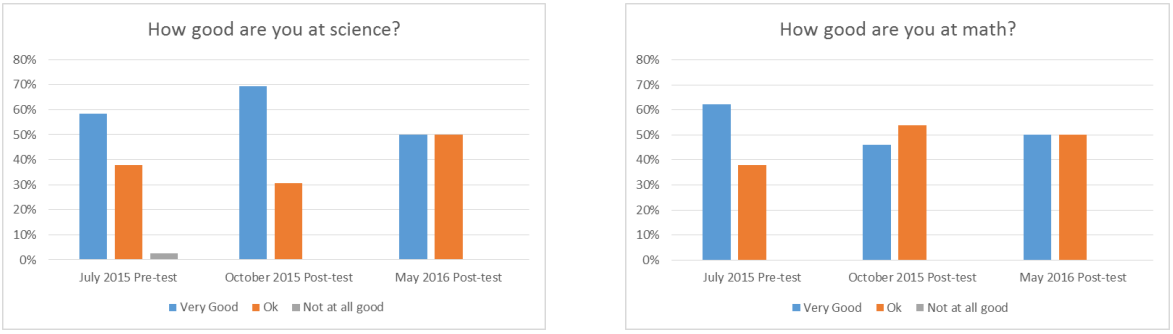

Figure 1: Participant attitudes about their science and mathematics abilities

2) Content knowledge: *Which of the following have you created? Mobile app, coding, website, video.* At the start of the program, no participant had created a mobile app, 11% had written code, 22% had created a website and 81% had created a video. Most students had done all four by the end of the program. Other questions not discussed: *Please fill in the circle that best describes your response:*[B] *I know what a 3D printer is. I know how a 3D printer operates. I understand how to use software to create a 3D design. I understand how to use software to create an app. I know how to work successfully in a team or group. Technology is useful for solving practical problems in life.*

3) Interest in STEM subjects: *Please rate your interest in taking classes in the following subjects in the future:* [C] *Science, Technology, Engineering, Math, Design.* Responses were collapsed to High (very), Medium (moderate/some) and Low (little/not). Interest increased in STEM subjects, particularly in science and engineering (Figure 2), but not mathematics. The increased science interest occurred, in spite of falling perceptions of science ability shown in Figure 1.

4) Interest in STEM careers: *Please rate your interest in a career in the following areas:* [C] *A career in science, A career in technology, A career in engineering, A career in 3D design, A career in app development.* Comparing 2015 to 2016, students rated themselves as very interested in careers in technology (56% vs 50%), engineering (50% vs. 50%) and 3D design (61% vs 58%%). While those that were very interested in science (42% vs. 33%) and math (53% vs 33%) careers fell.

5) Interest in attending college attendance: *Please fill in the circle that best describes your response:* [B] *I plan to finish high school, I plan to attend college.* By the end of the academic year, the number of students planning to finish high school increased from 83% to 100% and those planning to attend college increased from 75% to 92%.

Summary and Conclusions

Overall, the preliminary findings from this study suggests an approach for increasing minority male interest in computing and engineering related subjects, careers, and college attendance. It also points to a need to balance this interest with mathematics achievement, to ensure eligibility for STEM careers. Based on preliminary results, the mathematics instruction was modified in the summer of 2016 to be more tightly integrated with the other program activities. We are also investigating the proven practices used by groups that work to increase mathematics achievement in minority populations. In addition, we are reviewing our results from longitudinal tracking in the first two year, to determine modifications for 2017.

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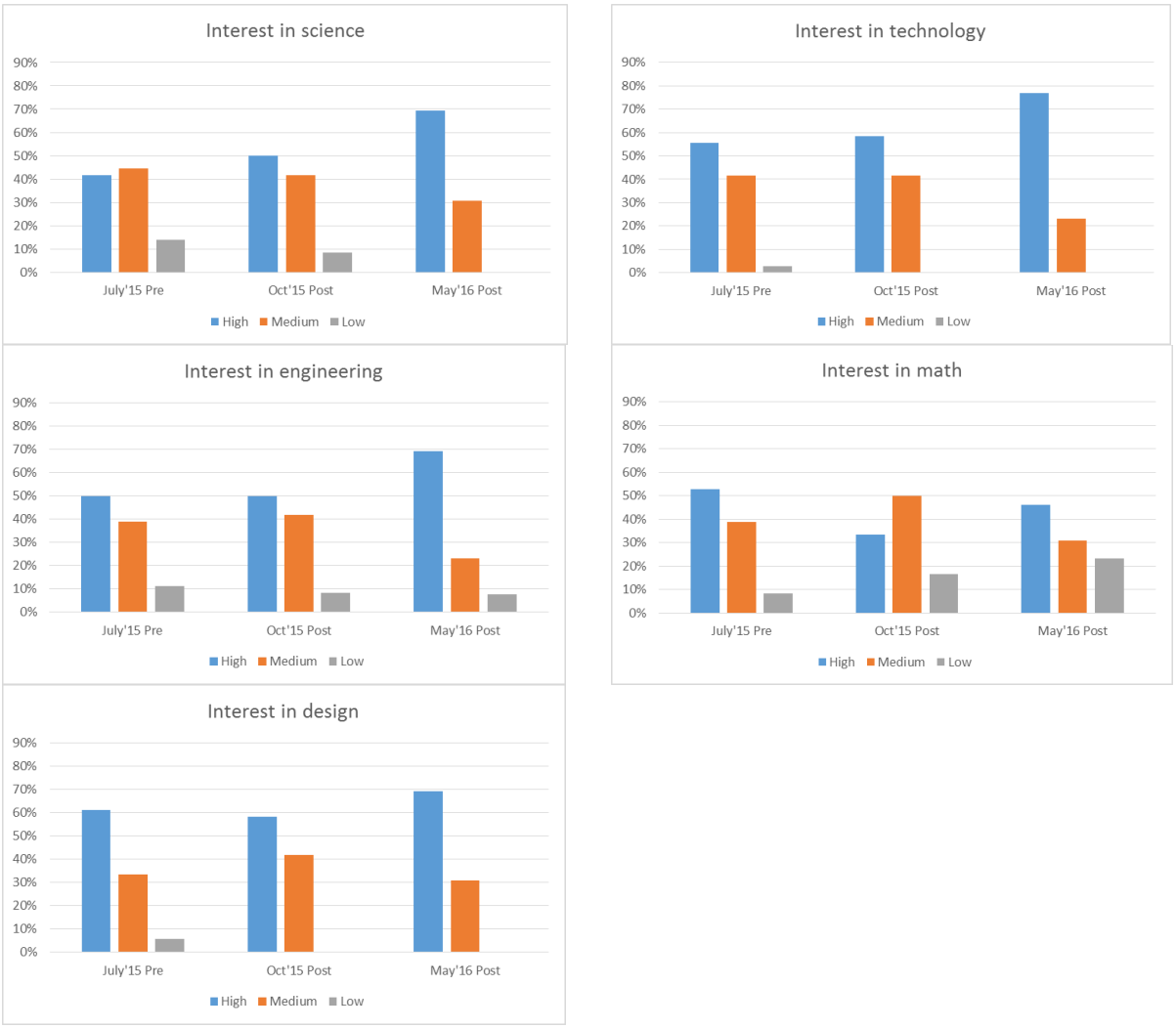

Figure 2: Participants' interest in taking science, technology, engineering, math, and design classes.

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