Engaging Underrepresented Students in Computer Science: Examining the Effectiveness of a 5-week Computer Science Course in the SMASH Summer Academy

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Abstract – *To alleviate barriers facing underrepresented students of color in pursuing computer science, the Level Playing Field Institute implemented a computer science course within its SMASH summer program, serving n=165 low-income, high school students of color. Aiming to examine the effectiveness of the intervention, this study utilized a pre- and post-program survey to measure student growth in computer science knowledge and aspirations. Results indicated that self-reported computer science skills and knowledge, and computer science aspirations significantly increased over the 5-week course. There were no significant differences by gender suggesting that the courses, curriculum, and instruction were effective for both males and females. Given current constraints within K-12 public education, this model for engagement and exposure to computer science in an out-of-school setting among students often marginalized from opportunities in computer science can inform strategies and interventions to increase participation, engagement, and retention in computer science among students of color.*

Keywords: African American, Latino/a, Computer Science Aspirations, Out-of-School Learning, Expanding Computer Science Opportunities

1 Introduction

Despite projections that the fastest-growing and highest-paying occupations of the future are in computing fields [1], underrepresented students of color continue to comprise an alarmingly small percentage of individuals taking computer science courses, pursuing computer science degrees, and entering the computing workforce. From 2008-2018, computer and mathematical occupations are expected to add over 785,000 new jobs, growing twice as fast as the average rate for all occupations (22% growth in 10 years) and being one of the top 10 fastest growing occupational groups [2]. In addition, computer and mathematical occupations are among the highest-paying occupations, with an average mean annual salary of $78,730 [3].

In California, home of Silicon Valley, and the state with the highest numbers of projected annual computing job openings [4], vast disparities by race and gender exist in access, opportunity, and outcomes in computer science from K-12 to the workforce. Across the entire state of California, just 45 African American students and 314 Latino students took the AP Computer Science A exam in 2012. Despite the fact that African American and Latino students comprise a combined 57% of the high-school aged population in California, they accounted for just 9% of all students taking the AP Computer Science A exam in 2012 [5][6]. Further, African American and Latino students combined account for just 17% of all computer science Bachelor's degrees conferred, 7% of all computer science Ph.D.'s conferred and 9% of the computing workforce nationwide [7][8]. These disparate outcomes can be linked to the following barriers impacting the pursuit of computer science among underrepresented students of color: (1) Lack of access to rigorous computer science courses, (2) Lack of engaging and relevant curriculum, and (3) Social and psychological barriers affecting perceptions of computer science.

1.1 Access to Rigorous Computer Science Courses

The Computer Science Teachers' Association recommends that all students participate in a sequence of 3 computer science courses at the high school level [9]. Yet, in many schools attended by students of color, if any computer courses are offered at all, they tend to focus on basic computer applications or typing [10][11]. Access to advanced computer science courses also varies by race/ethnicity, and schools serving high numbers of students of color are much less likely to offer rigorous computer science courses than more affluent schools [12]. Without access to Advanced Placement computer science courses, students are 8 times less likely to pursue computer science studies in higher education [13].

1.2 Curriculum

Within computing classes at the secondary level, curriculum can vary tremendously from courses focusing on typing and basic computer applications (e.g., Microsoft Word, Excel) to

creating mobile apps, to a strict focus on programming in Java [10][11]. A major challenge in the rigorous Advanced Placement computer science courses is making the content engaging, interesting, and relevant, especially when attempting to engage underrepresented students of color who have not typically enrolled in such courses [10][14]. Promising practices in revising computer science curriculum to engage a broader group of underrepresented students of color include the development of a new Computer Science Principles AP course to expand content beyond Java to provide an engaging, inspiring, and rigorous advanced course [15], the development of the Exploring Computer Science curriculum which introduces students to foundations of computer science within an inquiry-based and culturally relevant context [14], and additional interventions drawing upon theories of culturally relevant pedagogy [16] to engage students of color in computing [17][18][19]. These promising practices, however, are generally positioned within high schools and there remains a need for rigorous out-of-school computer science engagement to serve students without access to computer science courses within their high schools.

1.3 Social/Psychological Barriers

Even with access and opportunity, students of color are often discouraged or disinterested in studying computer science due to misconceptions about computer science as a discipline and career path [20][21][22], perceptions of computer science as lacking interpersonal or social relevance [23][24][25], lack of diverse role models [19][26][27][28], isolation [29], stereotype threat associated with being a member of a marginalized group in math and science [30], and the presence of stereotypical cues within computer science environments [31][32].

Interventions focusing not just on increasing access to rigorous computer science courses, but also on reshaping the pedagogical practices and curricula within computer science classrooms and alleviating social/psychological barriers have demonstrated positive outcomes among underrepresented students of color [14][19]. To address the barriers facing underrepresented populations and expand pathways to college and careers in computer science, the Level Playing Field Institute implemented an introductory computer science course within its Summer Math and Science Honors (SMASH) Academy, serving high school students of color in California. This study seeks to expand understanding of effective interventions for improving computer science outcomes among high school students of color by examining the effectiveness of the pilot introductory computer science course within the SMASH Academy. Specifically, this study aims to examine the following research questions: (1) What impact does participating in a 5-week computer science exposure course have on the computer science knowledge and computer science college and career aspirations of underrepresented high school students of color? and (2) Does course impact vary by demographic variables (e.g., gender, SES)?

2 Methodology

2.1 Program Context

The Summer Math and Science Honors Academy (SMASH) is a 3-year, 5-week summer STEM enrichment program serving predominantly low-income and first-generation underrepresented high school students of color. The SMASH program was designed in 2004 to alleviate the barriers facing underrepresented students of color in STEM by providing a rigorous, college preparatory summer academy to prepare high school students demonstrating interest and aptitude in studying STEM subjects to enter and persist in STEM studies at four-year universities. SMASH currently holds its summer programs at four university campus sites in Northern and Southern California (UC Berkeley, Stanford, UCLA, and USC).

Each SMASH site includes three cohorts of students, those entering 10^{th}, 11^{th}, and 12^{th} grades. To provide a comprehensive program which prepares students to be academically prepared for STEM studies in college, SMASH programming includes core math (Algebra II, Pre-Calculus, Calculus) and science courses (Biology, Chemistry, Physics), and elective courses including Science Writing, Mobile Apps, and Entrepreneurship. In addition, SMASH offers a college success course which guides students through the process of researching colleges, completing college applications, and researching and applying for financial aid. Finally, to counteract social/psychological barriers, SMASH exposes students to diverse STEM role models through a weekly "Speaker Series," employs a diverse teaching staff, and builds community and networks of support among SMASH students.

2.2 Participants

The study sample included n=165 high school students participating in SMASH at four sites in Northern and Southern California (UC Berkeley, Stanford, UCLA, and USC; See Table 1). Students were selected to participate in the summer program based on criteria including grades, performance in math and science courses, interest in STEM, and teacher recommendations. All students were members of ethnic groups underrepresented in the STEM fields, with the majority being Latino (57%) and African American (25%), with other underrepresented groups and multiracial students comprising the remaining 18%. The sample was equally divided based on gender, with 52% of scholars being female. The 3-year program serves students starting in the summer prior to their sophomore year through the summer prior to their senior year. The sample included rising 10^{th} graders (66%), rising 11^{th} graders (18%), and rising 12^{th} graders (16%). The vast majority of students were low-income (82%) and the first in their family to complete college (81%). All students attended high schools in the San Francisco Bay Area or in the Los Angeles Area; with 94% attending public or charter high schools. Academic data indicates that the average math grade for SMASH students is a "B+", the average

California Standards Test (CST) math score is 420, and the average CST science score is 428; both the math and science CST scores fall into the Proficient/Advanced range.

Table 1. SMASH Academy Demographic Data

		Gender		Race/Ethnicity			Socioeconomic Indicators	
SMASH Site	**(n) Students**	**Male**	**Female**	**Af-Am**	**Latino**	**Other**	**% FRPL**	**% First-in-Family**
UC Berkeley	28	50%	50%	18%	64%	18%	79%	86%
Stanford	79	51%	49%	28%	46%	26%	77%	81%
UCLA	29	45%	55%	41%	52%	7%	83%	72%
USC	28	43%	57%	7%	86%	7%	96%	86%
Total	165	48%	52%	25%	57%	18%	82%	81%

Methodological note: The total number of SMASH students attending a SMASH program in 2012 was n=214. Of these, n=165 (78%) both took a Computer Science course in the summer of 2012 and completed pre-SMASH and post-SMASH surveys. The data presented within this paper does not include students with unavailable data (n=7, 3%) or those who did not take Computer Science in 2012.

Just 36% of SMASH students attended a high school which offered any form of computer science course in 2011-2012. Further, just 17% of SMASH students attended a high school in which AP Computer Science A is offered (UCOP, 2013). Not surprisingly, 69% of SMASH students in 2012 indicated that they had never previously taken a computer science course of any kind.

2.3 Procedures

All students completed a pre-SMASH and post-SMASH survey administered online through SurveyMonkey at the beginning and at the end of the program (June and August 2012). The full survey contained items measuring 21 variables, including the target variables for this study which included a computer science concept/skills inventory, computer science coursetaking aspirations, and computer science college and career aspirations. Surveys took approximately 45 minutes to complete at both pre- and post-SMASH administrations. The mean of each scale at pre-SMASH at post-SMASH was calculated and a paired-samples T-test was run to determine if mean values were significantly different in pre- and post-SMASH conditions. Analyses of Variance were used to determine if significant differences in pre- and post-SMASH computer science outcomes existed based on demographic characteristics (e.g., race, gender).

2.4 Study Instruments

Study instruments consisted of a comprehensive online survey which included the two variables examined within this project: (1) Computer Science skills/knowledge, and (2) Computer Science aspirations. The Computer Science skills/knowledge scale (α=.85), consisted of an inventory of 5 items assessing student's self-reported skills and knowledge about basic computer science topics. The 5 topics were developed in collaboration with the course instructor and were consistent with the curriculum topics being covered within the 5-week course. Items included, "I know how to design and program a basic user interface," "I know how to structure a database," and "I understand the basic processes of debugging" and were scored on a 5-point Likert scale (Strongly disagree-Strongly agree).

The Computer Science Aspirations scale (α=.92), consists of two items assessing students interest in pursuing a computer science degree in college and interest in pursuing a career in computer science. Items included, "I plan to pursue a degree in computer science," and "I plan to pursue a career in computer science," and were scored on a 5-point Likert scale (Strongly disagree-Strongly agree). The survey also included one item assessing interest in pursuing a computer science course in high school. Demographic data for each scholar was collected upon admission to the program, and included: Race/Ethnicity, Gender, Grade, High School, FRPL eligibility, First-in-Family status, Mother and Father's Highest Education Level, among others.

2.5 Course Description

Computer Science was offered to all first, second, and third year SMASH students at Stanford, and to all first year SMASH students at UC Berkeley, UCLA, and USC. The curriculum was adapted from the Exploring Computer Science curriculum, of the Computer Science Equity Alliance at UCLA (www.exploringcs.com). The curriculum integrates culturally relevant pedagogy and inquiry-based learning with content standards to ensure students are engaged and are mastering content while understanding the application of concepts and skills to their everyday lives.

3 Summary of Findings

3.1 Computer Science Skills and Knowledge

On average, students began the computer science course with low levels of self-reported knowledge and skills in computer science (M=1.39, SD=.65). By the end of the course, students reported much higher levels of knowledge of basic computer science concepts (M=2.93, SD=1.08). Students demonstrated a significant increase in computer science skills and knowledge from pre- to post-SMASH conditions ($t(155) = -14.37$, $p=.00$; Table 2). When examining gender differences, males' self-reported skills (M=1.22, SD=1.01) demonstrated a larger increase than females' skills (M=.98, SD=.88), but the

difference was non-significant (F(154)=2.42, p=.12). In addition, no significant differences were found in pre-post Computer Science skills by FRPL-eligibility status, high school grade, or race/ethnicity.

3.2 Computer Science Aspirations

Prior to taking the course, students had relatively high levels of Computer Science college and career aspirations (M=2.93, SD=.83), and these aspirations increased slightly by the end of the course (M=3.04, SD=.95). Students demonstrated a significant increase in computer science college and career aspirations from pre- to post-SMASH conditions (t(154)=-1.61, p=.10; Table 2). Female students demonstrated a slightly larger increase in computer science aspirations (M=.17, SD=.87) than their male counterparts (M=.05, SD=.82), but the difference was non-significant (F(153)=.77, p=.38). There were no significant differences found in pre- and post-Computer Science aspirations by race/ethnicity, or FRPL-eligibility status.

Table 2. Paired-Samples T-Test: Pre- and Post-SMASH Computer Science Outcomes

Scale	Pre-SMASH (Mean)	Post-SMASH (Mean)	Diff.	SD	t	Sig. (2-tailed)
Computer Science Skills/ Knowledge	1.39	2.48	-1.09	.95	-14.37	.00**
Computer Science Aspirations	2.93	3.04	-.11	.84	-1.62	.10*

p<.00**, p<.10*

4 Conclusion and Implications

Preliminary evidence from the first year of the SMASH computer science course indicates that the 5-week course significantly increased self-reported computer science skills and knowledge, and computer science aspirations among underrepresented high school students. There were no significant differences by gender, suggesting that the courses, curriculum, and instruction were effective for both males and females. To expand understanding of the effectiveness of this computer science intervention, future research can utilize comprehensive formative assessments in addition to self-report surveys and can further examine with students and instructors the most and least engaging elements of the computer science introductory content in order to understand how experiences can lead to interest, aspirations, and persistence in computer science. In addition, further research is needed to examine the longitudinal impact of exposure to computer science interventions, such as the SMASH 5-week course, on the high school coursetaking and likelihood of majoring and persisting in computer science in post-secondary education. Given current constraints within K-12 public education, this model for early engagement with and exposure to computer science in an out-of-school setting among students often marginalized from opportunities in computer science can inform strategies and interventions to increase participation, engagement, preparation, and retention in computer science among students of color.

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