Rigor, Role Models, and Relevance: Examining the Impact of A Culturally-Relevant STEM Intervention Program for Underrepresented High School Students of Color

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BACKGROUND

Underrepresentation in Science, Technology, Engineering, and Math (STEM)

- Women and underrepresented minorities account for 70% of all undergraduate students, but just 45% of students enrolled in all science and engineering baccalaureate programs (PCAST, 2012).

- African Americans and Latinos comprise **29%** of the total U.S. population and:
  - **15%** of all Advanced Placement math and science test takers (College Board, 2013)
  - **11%** of all Science and Engineering Bachelor's degrees conferred
  - **12%** of all students enrolled in graduate studies in science and engineering (NSF, 2009)
  - **9%** of the entire science and engineering workforce (NSF, 2012).

Why Underrepresentation Matters

- The demand for a skilled STEM workforce is rapidly increasing, specifically within computing fields (CEW, 2011).
- U.S. is failing to produce the number of STEM graduates to meet this increasing demand; approximately 1 million additional STEM graduates must be produced in the next 10 years, beyond current rates (PCAST, 2012).
- Underrepresented populations in STEM represent a large pool of untapped talent and potential.
- Inequities in STEM also restrict underrepresented individuals from the highest-paying and fastest-growing occupations of the future, impacting both individual and community-level economic outcomes.

Barriers Affecting STEM Opportunities and Outcomes

- **Structural barriers**
  - Inequitable school funding and resources (EdTrust West, 2012)
  - Lack of access to science resources and facilities (WestEd CFTL, 2011)
  - Inequitable access to high-quality teachers (Darling-Hammond, 2004; U.S. Dept of Ed., 2008)
  - Disparities in computer science course offerings (Margolis et al., 2008)
  - Lack of opportunity to engage with technology to solve problems, conduct experiments, or create products (Goode, 2010; Gray, Thomas & Lewis, 2010)
  - Unequal access to and participation in advanced coursework (College Board, 2012)

- **Social/Psychological barriers**
  - Stigmatization (Major & O'Brien, 2005)
  - Isolation (Chang et al., 2011; Perna et al., 2009)
  - Stereotype threat (Steele & Aronson, 1995)
  - Lack of diverse STEM role models and peer support networks (Astin & Astin, 1992; Price, 2010).

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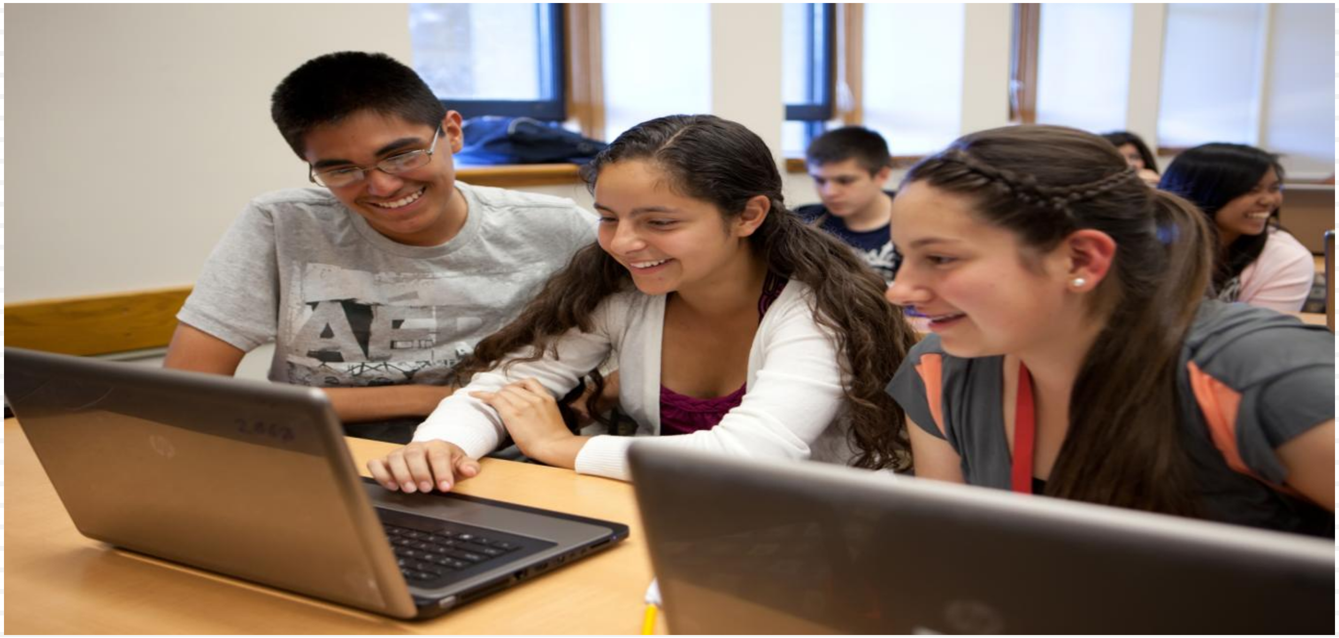
THEORETICAL & CONCEPTUAL FRAMEWORK



Culturally Relevant and Responsive Pedagogy as a Framework for Intervention

- Culturally relevant pedagogy and culturally responsive pedagogy are models for effective pedagogical practice that utilize the cultural characteristics, experiences, and perspectives of ethnically diverse students to teach students more effectively (Gay, 2000), while helping them affirm their cultural identity, and encourage their development of critical perspectives to challenge institutional inequities (Ladson-Billings, 1995).

- 3 Tenets of Culturally Relevant Pedagogy (Ladson-Billings, 1995):
  - Academic Achievement: Implementing rigor and demanding high levels of academic achievement
  - Cultural Competence: Maintaining cultural integrity, honoring student's cultural backgrounds, and developing high levels of cultural competence, and
  - Critical Consciousness: Helping students to understand, recognize, and critique social inequities
- 4 Critical Components of Culturally Responsive Teaching (Gay, 2000)
  - Developing teachers who are critically conscious of their own cultural socialization and how it affects students,
  - Developing warm, caring, supportive, and demanding classroom environments,
  - Developing communities of learners within classrooms to support academic, social, and cultural development,
  - Implementing multicultural curriculum and culturally congruent instruction which includes information about the histories, cultures, and contributions of different cultural groups in all subjects.

Conceptual Framework

Table 1. Summarizes the conceptual framework guiding program development, programming components and evaluation of impact

BARRIERS

- Lack of Access to Rigorous Coursework
- Lack of Access to Support Networks
- Social/Psychological Barriers

Culturally Relevant and Responsive Pedagogical Framework

INTERVENTIONS

- Accelerated math and science courses
- Exposure to computer science courses
- Diverse STEM role models, peers, and instructors
- Community-building among STEM peers

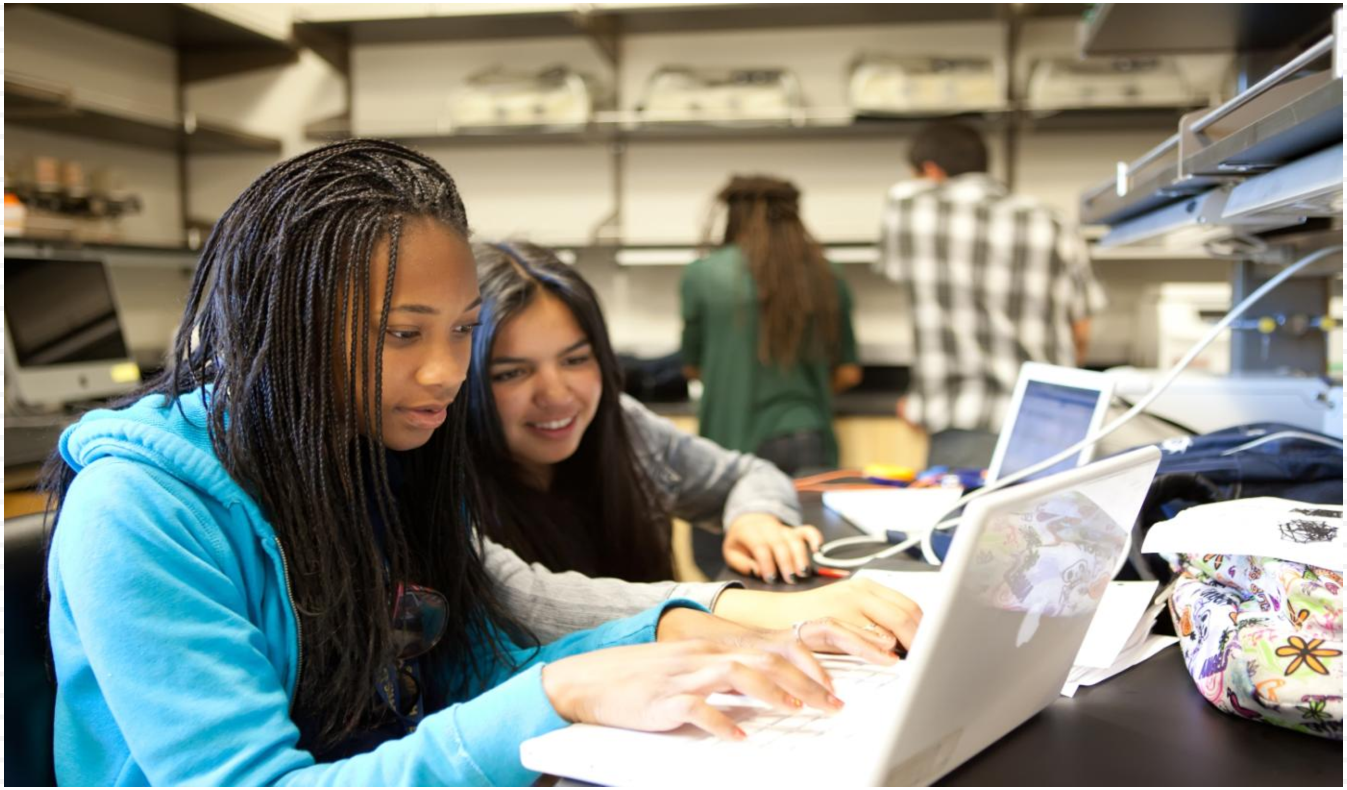
SHORT-TERM OUTCOMES

- Math content knowledge
- Computer science skills
- Access to STEM role models
- Network of STEM peers
- Attitudes towards math and science
- Identification with math and science
- Self-efficacy
- STEM college and career aspirations
- Negative racial stereotypes (-)
- Perceived barriers (-)

LONG-TERM OUTCOMES

- Declare STEM major
- Persist in STEM
- Graduate with STEM degree

STUDY OVERVIEW



Study Purpose

- This study will:
  - Expand upon existing knowledge about effective STEM intervention programming
  - Examine a the impact of a STEM intervention program utilizing a culturally relevant and responsive pedagogical programming framework
  - Contribute to understanding on ways to improve STEM educational outcomes among underrepresented groups

Research Questions

(1) To what extent is the STEM intervention program successful in addressing the barriers faced by underrepresented high school students including the lack of access to rigorous STEM coursework, the lack of access to diverse networks of support in STEM, and psychological barriers (e.g., disidentification) in attitudes towards STEM?

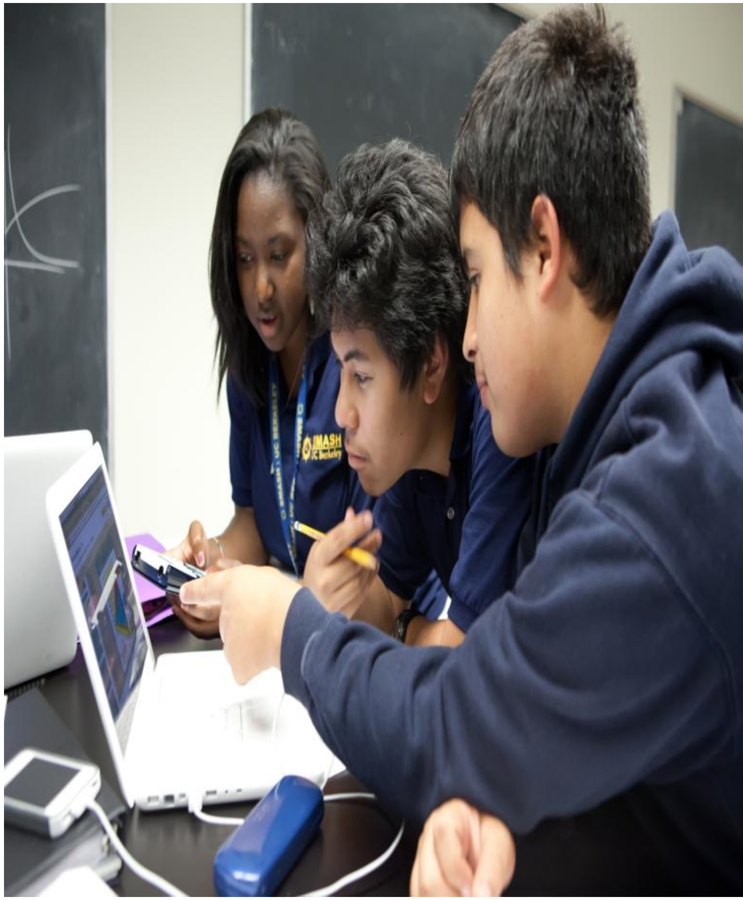
(2) Does participation in the STEM intervention program have an impact on the STEM college and career aspirations of underrepresented high school students?

(3) To what extent is this program successful in developing leadership skills, developing cultural competency skills, and developing an orientation towards using STEM knowledge to address issues of relevance to underrepresented communities?

Program Context and Participants

- 5-week, 3-year STEM summer residential program held on 4 college campuses in California
- n=207 9-12th grade public HS students

Demographic Variables		Percentage of Sample
GENDER	Male	49%
	Female	51%
RACE/ETHNICITY	African American	25%
	Latino	53%
	Vietnamese	5%
	Other (Mixed, Other Southeast Asian)	17%
GRADE LEVEL	10th	53%
	11th	26%
	12th	22%
SES INDICATORS	Free/Reduced Price Lunch-Eligible	76%
	First-in-Family to Complete College	77%



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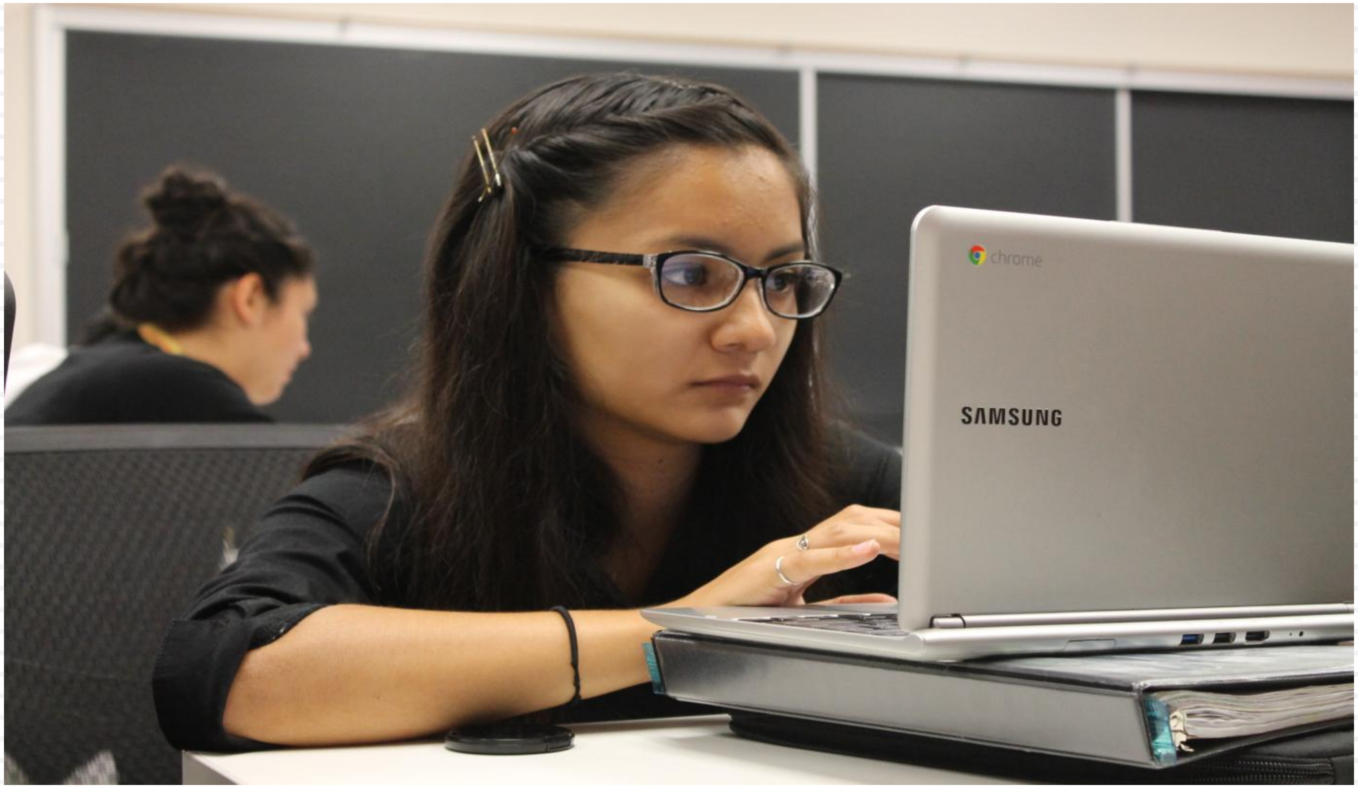
Programming and Curriculum

- Curriculum
  - Core mathematics (Algebra II, Pre-Calculus, Calculus) and science (Biology, Chemistry, Physics) enrichment courses
  - 3-year AP Computer Science preparatory sequence of courses (CS1, CS2, CS3)
  - College success classes (e.g., college applications), youth development curriculum (e.g., leadership, public speaking)
  - Core curriculum integrates project-based learning, culturally relevant pedagogy, and technology
- Role Models, Mentors, STEM Peer Networks
  - Exposure to diverse STEM role models through weekly "Speaker Series"
  - Facilitation of community-building and support networks among peers
  - Field trips and guest lectures during the academic year
- Youth Development Curriculum
  - Activities focused on cultural competence, social justice orientation, leadership and critical thinking skills
  - Workshops (e.g., SAT prep) during the academic year
  - College success classes during all 3 years (e.g., college applications, financial aid)

METHODOLOGY



Design, Data Collection & Analytical Procedures

- ***Design***
  - Utilized a one-group pre-test post-test design to examine the impact of the summer STEM intervention program on student outcomes
- ***Data Collection Procedures***
  - The following quantitative data were collected:
    - (1) a **pre-program survey** at the start of the program which assessed variables including attitudes towards math and science, STEM aspirations, access to role models, identification with math and science, perceived barriers and stereotypes, and self-concept, among others, and a **post-program survey** at the completion of the program assessing the same variables,
    - (2) a pre- and post-program **mathematics** assessment
    - (3) a pre- and post-program content knowledge assessment in **computer science**
- ***Analytical Procedures***
  - To determine whether changes in variables occur from pre- to post-intervention, paired-samples T-tests were run to determine if mean scale values change significantly over time.

Study Instruments

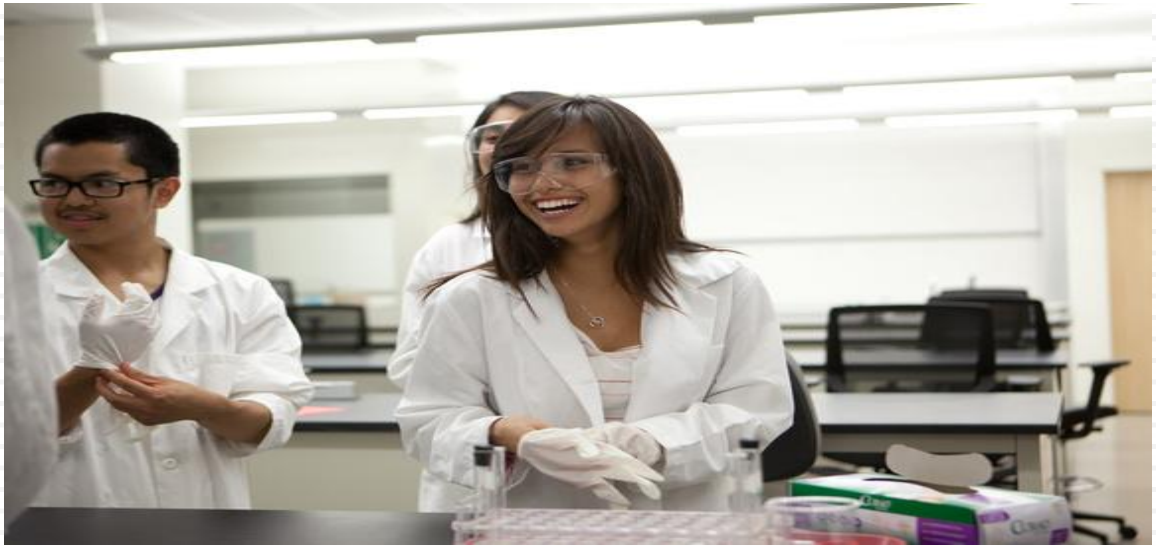
- **Mathematics Assessment.** The pre- and post-intervention mathematics readiness assessment from the Mathematics Diagnostic Testing Project (MDTP, 2012) was taken by all students according to grade level (Algebra II, Mathematics Readiness, Calculus Readiness, and Beginning Calculus).

- **Computer Science Concept Inventory.** Self-reported computer science skills using 5-item skill inventory, including: familiarity with structuring databases, designing program interfaces, and understanding debugging and loop controls (α=.85, 5 items rated on a 5-point Likert scale).

- **Pre- and Post-Survey.** 14 scales are examined within this study including:
  - Access to STEM role models (α=.81, 3 items),
  - Network of STEM peers (α=.63, 4 items),
  - Attitudes towards math (α=.82, 2 items) and science (α=.88, 2 items),
  - Identification with math (α=.72; 4 items) and science (α=.80; 4 items),
  - STEM college aspirations (α=.93; 2 items) and STEM career aspirations (α=.89; 2 items),
  - Computer science aspirations (α=.78; 3 items),
  - Social justice orientation (α=.62; 3 items),
  - Cultural competence (α=.73, 2 items),
  - Leadership skills (α=.86; 4 items).

Note: All survey scales were developed in consultation with the literature, and some have been adapted from previously-tested scales (Eccles & Wigfield, 1995; Scott, 2011). All scales are rated on a 5-point Likert scale (1=Strongly Disagree, 5=Strongly Agree).

OVERVIEW OF FINDINGS



Alleviating Barriers to STEM

- Over the course of the 5-week intervention:
  - Student demonstrated a statistically significant increase in **math performance,** increasing their skills and preparation for advanced level high school mathematics courses.
  - Students' **computer science knowledge and skills** increased significantly, providing both CS exposure (most students had never previously taken a course) and skill development.
  - The program strategically exposed students to diverse STEM role models and this had a significant, positive impact on students: they reported a significant increase in **access to STEM role models.**
  - Being exposed to other high school students of color and participating in community building activities also resulted in a significant increase in **access to networks of STEM peers**.
  - No significant changes in attitudes towards math and science, and identification with math and science.

Scale	**Mean Diff (Pre-Post)**	**SD**	***t***	**Sig. (2-tailed)**
Mathematics Achievement	-.05	.11	-5.68	**.00****
Computer Science Skills	-.92	.98	-13.3	**.00****
Access to STEM Role Models	-.24	.90	-3.8	**.00****
Access to Networks of STEM Peers	-.12	.66	-2.58	**.01****
Attitudes towards Math	-.03	.51	-.70	.49
Attitudes towards Science	-.02	.55	-.49	.62
Identification with Math	-.02	.29	-.95	.34
Identification with Science	.05	.46	1.42	.16

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STEM Aspirations

- Over the course of the 5-week intervention:
  - There was a significant increase in students' **aspirations to study computer science** in college and to pursue a career in computer science demonstrating that the computer science course had a significant impact on student aspirations within computer science.
  - Students demonstrated small, but insignificant increases in both the intention to pursue STEM studies in college and the desire to pursue a career in a STEM field. In computer

Scale	Mean Diff (Pre-Post)	SD	*t*	Sig. (2-tailed)
STEM College Aspirations	-.09	.94	-1.41	.16
STEM Career Aspirations	-.02	.97	-.33	.74
Computer Science Aspirations	-.11	.83	-2.0	.04**

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Leadership Skills, Cultural Competency & Social Justice Orientation

- This intervention program sought to not only increase students' STEM skills and aspirations, but to also develop and utilize their skills to be change agents within their communities.
- Over the course of the 5-week intervention:
  - Students demonstrated a statistically significant increase in their cultural competency, leadership skills, and orientation towards using STEM skills and knowledge to improve their communities

Scale	**Mean Diff (Pre-Post)**	**SD**	***t***	**Sig. (2-tailed)**
Cultural Competency	-.15	.83	-2.70	**.01****
Leadership Skills	-.16	.55	-4.2	**.00****
Social Justice STEM Orientation	-.07	.53	-1.88	**.06***

Summary and Significance of Findings

- Taken together, results reveal that:
  - Exposure to rigorous STEM courses increase mathematics performance and computer science skills and knowledge
  - Exposure to diverse STEM role models and participating in community building activities had a significant impact on access to STEM peers and role models, which are critical components associated with persistence in STEM (Eagan et al., 2010).
  - Participating in a 5-week computer science course significantly increased computer science college and career aspirations, extending previous research by Goode & Margolis (2011) and contributing to understanding of ways to increase CS outcomes among underrepresented groups.
  - The program succeeded in increasing BOTH STEM skills and leadership, cultural competency, and social justice orientation, preparing students to be change agents within their communities.

- These results contribute to literature on increasing STEM participation and outcomes among underrepresented populations, in the CRRP framework for curriculum and programming, and the intervention components which are linked directly to barriers in STEM.
- Additional research needed to further examine CRRP curriculum and pedagogical strategies within STEM courses and interventions and to understand mechanisms which contribute to increases in performance outcomes.

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THANK YOU

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- For more information about this study or related research and STEM programming for middle and high-school students:
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